Proceedings of a Seminar on

Crop Protection for Resource-Poor Farmers

Isle of Thorns Conference Centre, East Sussex, United Kingdom
4-8 November 1991

CTA
Technical Centre for Agricultural and Rural Cooperation
ACP-EEC Lomé Convention

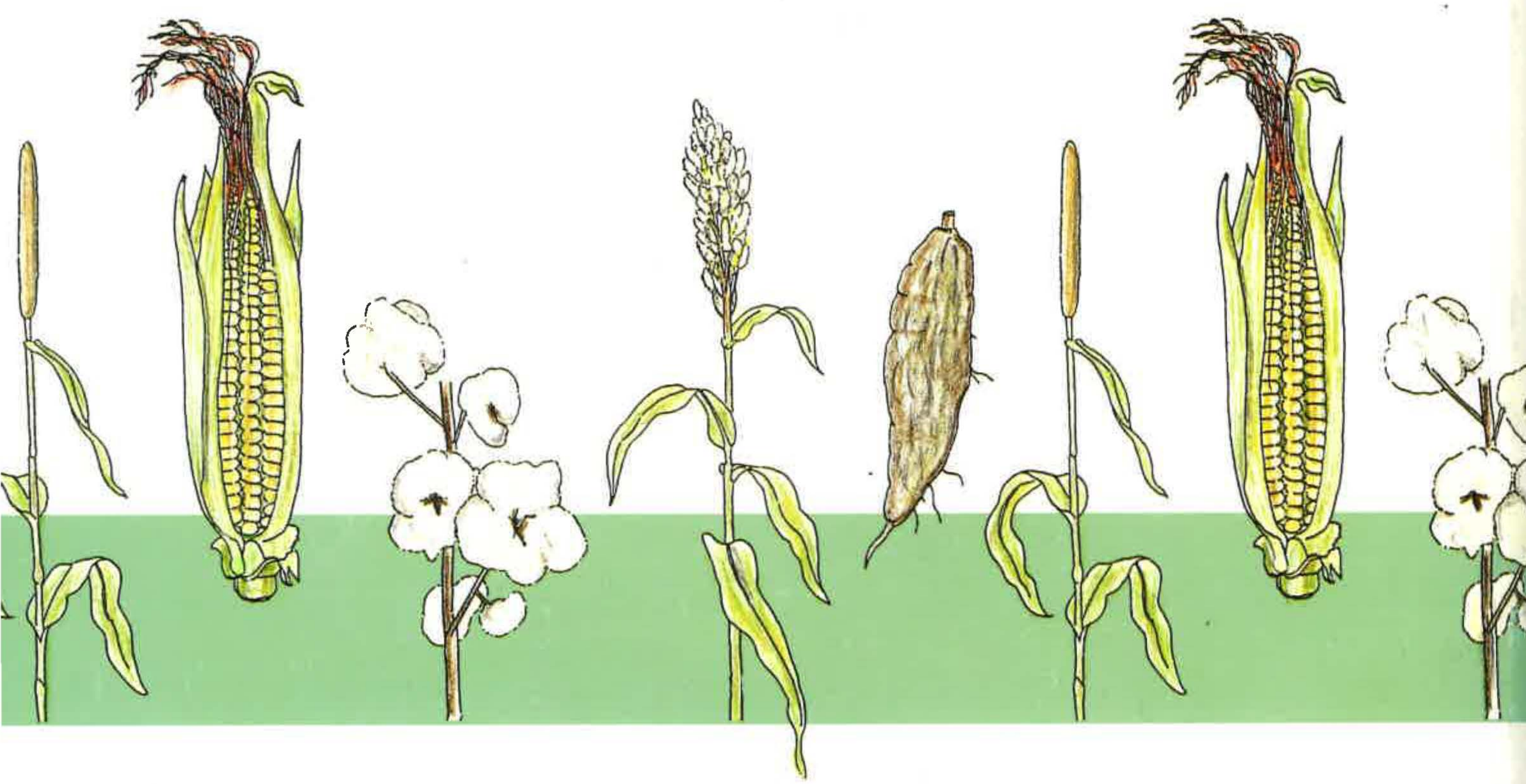
Headquarters
'De Rietkampen', Galvanistraat 9
Ede, The Netherlands

Postal Address
Postbus 380
6700 AJ Wageningen
The Netherlands
Tel. (0)8380-60400
Fax. (0)8380-31052
Telex 30169 cta nl

Brussels Branch Office
Rue de l'Industrie 4
1040 Brussels, Belgium
Tel. (0)2 513 74 35/6
Telex 20577 cta bxl b

NRI
Natural Resources Institute

Headquarters
Central Avenue, Chatham Maritime
Kent ME4 4TB, United Kingdom
Tel. 0634 880088 (National)
44 634 880088 (International)
Fax. 0634 880066/77
Telex 263907/8 LDN G
Telegrams NRI Chatham



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Edited by R. W. Gibson and A. Sweetmore

Natural Resources Institute, Chatham, Kent ME4 4TB, UK

TECHNICAL CENTRE FOR AGRICULTURAL AND RURAL CO-OPERATION (CTA)

NATURAL RESOURCES INSTITUTE (NRI)

CTA

The Technical Centre for Agricultural and Rural Co-operation (CTA) operates under the Lomé Convention between member States of the European Community and the African, Caribbean and Pacific (ACP) States.

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The Natural Resources Institute (NRI) is an internationally recognized centre of expertise on the natural resources sector in developing countries. It forms an integral part of the British Government's overseas aid programme. Its principal aim is to alleviate poverty and hardship in developing countries by increasing the productivity of their renewable natural resources. NRI's main fields of expertise are resource assessment and farming systems, integrated pest management, food science and crop utilization.

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PROCEEDINGS OF A SEMINAR ON CROP PROTECTION FOR RESOURCE-POOR FARMERS

PREFACE

Crop losses due to pests, weeds and diseases still exceed 30% in many tropical countries despite recent advances in crop protection. For technical and socio-economic reasons, it has proved difficult for resource-poor farmers to adopt new technologies. There are also health and environmental considerations where toxic chemicals are involved. The objective of the CTA/NRI seminar on Crop Protection for Resource-Poor Farmers was to provide a forum to examine and evaluate approaches to pest control, ranging from traditional practices to 'western', high-technology approaches; to consider the relevance and usefulness of the latter to resource-poor farmers; to identify which of the modern and traditional technologies are most likely to benefit farmers in the African, Caribbean and Pacific countries; and to propose means of promoting them.

Over the past three or four years there has been increasing awareness at the international level of the importance of integrated pest management (IPM), and an International IPM Working Group has been established to co-ordinate efforts in crop protection and to promote the implementation of IPM-based approaches. IPM has arisen largely in response to pesticide crisis situations - there are well-known problems associated with pesticide use including the development of secondary pests, resurgence, and resistance, as well as health and environmental hazards. IPM maximizes the use of natural regulatory mechanisms, and has been adopted most readily in response to situations in which pesticides are no longer effective. However, the IPM approach is also more widely applicable to low-input crop production systems, a concept of pest management using the most appropriate technology available to the farmer. It is often more difficult to put this approach into practice where there is no clear crisis to address.

In many of the African, Caribbean and Pacific countries, the primary need is to increase yields by improving crop protection, which will often involve the use of agrochemicals to a greater extent than they are used today. This is a very different situation from the context in which IPM has classically been applied. IPM involves mixing appropriate technologies, and its first objective is to increase agricultural production in a sustainable manner.

It is significant that the first contribution in this book is from a social scientist. IPM is an approach to pest management that must be operated by the user - the power for decision-making is transferred to the farmer, who must take the responsibility for analysing the crop protection needs within his own system. An understanding of the farmer's social, economic and cultural environment is absolutely crucial for effective implementation of IPM. IPM is not prescriptive; it can provide the tools and the understanding, but the end-user must choose to adopt this approach and be able to use the component technologies appropriately for the system to yield rewards.

Technology which stays in the laboratory does good to no one. It was once widely assumed that it was easy to determine which were the most appropriate new technologies for improving agricultural output. We now know just how carefully we need to consider which technologies are appropriate, what the consequences of their adoption might be, and how they might best be adapted and employed to alleviate rural poverty. Although we frequently have to admit that we do not have all the answers, we are getting better at asking the right questions. Opportunities to benefit from external resources do not automatically present themselves to the rural poor. That is our role: we need to maintain an awareness of changing development needs and new technological, social and economic developments, and we need to be vigilant in monitoring and reviewing the effectiveness with which technologies are being applied to today's problems.

All too frequently, specific research topics are addressed in great depth by technical specialists with narrow perspectives - the subsistence farmer cannot share the luxury of such technical specialization, and it is important to examine technical issues from his/her broader perspective. We as scientists also need to carry out a certain amount of self-examination to assess the extent to which our activities are really helping farmers to manage pest problems at the farm level. The aim of this seminar was to provide an opportunity to address these issues, to exchange ideas and to identify solutions.

Alan Jackson
Technical Adviser, CTA

John Perfect
Head of Pest Management Division, NRI

KEYNOTE ADDRESS

Scientist or resource-poor farmer - whose knowledge counts?

R. CHAMBERS

Institute of Development Studies, University of Sussex, Brighton BN1 9RE, UK

ABSTRACT

Hindsight shows that we scientists have often been wrong concerning tropical agriculture, and it is important that we recognize our limitations - we may have more knowledge about microscopic matters, but local farmers probably know more where continued observation and knowledge of inter-relationships are involved. Green-revolution agriculture has been effective mostly in flat, irrigated lands where farmers can control the environment. In contrast, most rainfed tropical agriculture occurs in complex, diverse and risk-prone environments. Research stations even in such areas tend to be resource-rich, and have led to only incremental gains for resource-poor farmers.

Farmers develop diverse cropping systems in response to an uncertain environment, and our discipline-oriented training neglects their complex linkages. Our role should be to provide farmers with information, allowing them to make the decisions and analyses, and accepting that they are fully capable. However, as well as recognizing that it is the farmer's knowledge which counts and the farmer who chooses, we must also ask, who gains and, especially, which farmer?

RESUME

Après coup l'on voit souvent que nous, les chercheurs, avons fait erreur en matière d'agriculture tropicale et il est important que nous reconnaissions nos limitations. Il est possible que nous ayons plus de connaissances sur les matières microscopiques mais les paysans en savent probablement plus lorsqu'il s'agit d'une observation continue et des relations entre différents éléments. La révolution verte en agriculture a surtout été efficace dans les plaines irriguées, où les paysans peuvent contrôler l'environnement. La plupart de l'agriculture tropicale pluviale se trouve au contraire dans des environnements complexes, divers et sujets aux risques. Même dans de tels endroits, les stations de recherche ont tendance à avoir beaucoup de ressources et leurs travaux ont uniquement conduit à des gains incrémentiels pour les paysans disposant de peu de ressources.

Les paysans mettent au point des systèmes de culture divers pour répondre à un environnement incertain et notre formation avec son orientation par discipline néglige leurs liens complexes. Notre rôle devrait être de fournir une information aux paysans, de les laisser prendre les décisions et effectuer les analyses, en acceptant le fait qu'ils en sont tout à fait capables. Toutefois, tout en reconnaissant que ce sont les connaissances du paysan qui comptent et que c'est le paysan qui choisit, nous devons aussi nous demander qui y gagne et, en particulier, quel type de paysan?

CONTEXT

We are lucky to be living in a period of rapid professional change. In integrated pest management (IPM), as in other domains, there have been rapid developments over the past two decades both in our understanding and in the tools we have available for interventions and management. Other changes have been taking place in all the major professions concerned with rural development. This is exciting, even exhilarating. But for all of us, there is also a sense in which we are unfortunate, because so often the professional training we have received proves a handicap. Not only understanding, but also methods and roles have changed, and scientists are now called upon to do things they were not originally trained to do. The challenge and the opportunity is not just professional, it is also personal - to unlearn old things, to learn new ones, and continuously to adapt to change.

I shall first talk about ignorance and knowledge, then about past failures, and then suggest some potential solutions. Finally, I shall pose three questions.

IGNORANCE AND KNOWLEDGE

It is striking, and humbling, in both the social sciences and the more technical fields, how often in the past we have been wrong while so sure we were right. The history of development is littered with examples. In agriculture, one example is the widespread belief, still repeated, that post-harvest losses of grain at the village level are of the order of 30% - again and again, when careful research has been conducted, the losses have been found to be only of the order of 4-8%. Another example, told to me by David Lyon (Natural Resources Institute), is of ten years' research in northern Nigeria based on planting cotton at the time optimal for yields - the start of the rains. Farmers declined to plant their cotton then, giving priority to their food crops, and planted their cotton only later. The lesson, painful to learn, was that since farmers were always going to plant their cotton late, it made no sense to do research to maximize yields at the optimum time from an agronomic point of view. Yet another example has been our ignorance, which looks surprising with the knowledge we have now, in advocating heavy pesticide applications.

Since we have so often been wrong in the past, we are probably still wrong on many counts. Recognizing our errors is fundamental to the learning process. And we can expect that some of today's conventional wisdom will, in five or ten years' time, also prove to have been wrong. The lesson is that we must continuously question our beliefs and practices, and always be ready to adapt and alter them as we learn more. There is no permanent, normal professionalism which we can adopt for life, and especially not with complex interactive management systems like IPM.

Recognition of our errors and limitations raises the question of the comparative advantages of our knowledge and farmers' knowledge. This is illustrated in Figure 1. The researcher's and the farmer's knowledge can be shown in a simple matrix (Figure 1a). If we, as scientists, look at ourselves, we will admit that the most acceptable position for us - the best for our egos and self esteem - is box 1: we know, and farmers do not know. Where farmers and scientists both know, and where they both do not know, we are on more or less equal footing (although quite often we pretend we know when we do not know). The least acceptable to us has been box 4, where the farmers know and we do not know. And yet that is often the most fascinating.

It is useful to consider our ideas of the relative sizes and content of these boxes, for pests and diseases, and

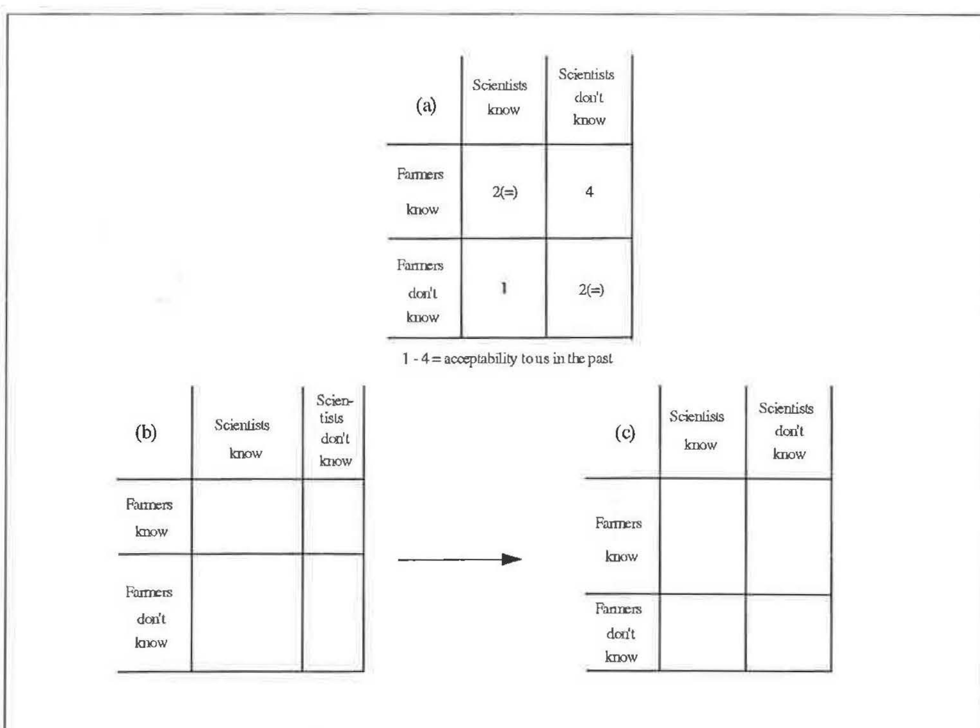


Figure 1 Whose knowledge? Changes in 'our' perceptions in the past two decades. (The sizes of the boxes represent amount and importance of knowledge and ignorance; 1-4 = acceptability to us in the past.)

Table 1 Industrial, green revolution agriculture and CDR agriculture compared

	Industrial and green revolution agriculture	Resource-poor (CDR) agriculture
Main locations	Industrialized north, Asian 'core' areas of irrigation	Rain-fed tropics, hinterlands, hills, swamps, undulating land, drought and flood-prone etc.
Farming systems	Simple	Complex (C)
Environmental variation	Uniform	Diverse (D)
Stability	Low risk	Risky (R)
Similarity of research station and farmers' conditions	High	Low
No. of scientists and extensionists per farming system	Many more	Many fewer
Farmers consulted about research priorities	Richer farmers sometimes	Rarely
Priorities for anti-poverty and production	Ind: Reduce production GR: Maintain production	Raise and stabilize production
Current production as percentage of sustainable production	Ind: Far too high GR: Near limit	Low!
Applicability of transfer-of-technology	Fairly good in the past	Poor

for their management. I would suggest that in the past we thought the boxes were as shown in Figure 1b: there was a lot that scientists knew and farmers did not, and there was a bit that both knew, but there was not much that farmers knew which we did not. With growing wisdom, particularly through work with resource-poor farmers over the past ten years, the size of these boxes in our professional consciousness has become more like Figure 1c. Of course, the relative sizes vary by context, by subject, and in other ways, but we recognise now that farmers' knowledge is substantial.

It is revealing to fill in the four boxes and see what goes where. Scientists have an advantage with things which are microscopic, including tiny pests, bacteria and viruses. Farmers, though, have an advantage with what can be seen with the naked eye, where continuous field observation matters, and concerning the intricate relationships of their farming systems. Their knowledge is particularly important for IPM because their observations link with community participation and collaboration. Farmers are not ignorant and stupid, as some have believed in the past; they know more than we used to realize. But nor are they always knowledgeable and right about everything. As Bentley & Andrews (1991) have observed:

> "Anthropologists and sensitized agricultural scientists need to avoid romanticizing or sentimentalizing traditional farmers at the same time as they take their knowledge and opinions seriously."

EXPLAINING PAST FAILURES

Let us now consider our rather dismal record in the agricultural and social sciences in serving resource-poor farmers. It is commonly said, in India, that only about 20% of all the technology generated in agricultural research is ever adopted by farmers. (There are some who consider 20% far too optimistically high.) Whatever the figure, all agree that there is a huge wastage. What is wrong and what could be done to improve performance? One approach is to reflect on different types of agriculture in the world. The Brundtland Commission - the World Commission on Environment and Development - categorized types of agriculture into three broad classes: industrial agriculture consisting of large fields under monoculture and plantations; green-revolution agriculture, which was mainly irrigated on flat plains, much of this being in Asia; and a third, complex, diverse and risk-prone (CDR) agriculture, as practised by most resource-poor farmers in the world (Table 1). In industrial and green-revolution agriculture, production has in the past been increased through simplification and standardization. This can be called a 'Model T' approach to agriculture, after the

Table 2 Typical contrasts in physical conditions between research stations and farming systems

	Research experiment station	Resource-rich farm	Resource-poor farm
Topography	Flat or terraced	Flat or terraced	Undulating, sloping
Soils	Deep, fertile	Deep, fertile	Shallow, infertile
Macro and micro nutrient deficiency	Rare Remediable	Occasional	Quite common
Plot size and shape	Large, square	Large	Small, irregular
Hazards	Nil or few	Few, controllable	Many - flood, drought, animals grazing crops etc.
Irrigation	Usually	Often	Often none
Size of management unit	Large, contiguous	Large or medium, contiguous	Small, often fragmented
Natural vegetation	Eliminated	Eliminated	Used or controlled

remark attributed to Henry Ford concerning his famous first mass-produced popular car: "The American public can have their Model T any colour they like as long as it's black". This has been the tendency with both industrial and green-revolution agriculture: to standardize and simplify in a package, always the same variety and the same advice. In this approach, the environment is controlled, E is made to fit G, the environment to fit the genotype.

These conditions contrast with the complex, diverse and risk-prone agriculture of most of the rainfed tropics where there are hills, swamps, undulating land, drought, risk of flooding, and other hazards. This includes much of sub-Saharan Africa. World-wide, this CDR agriculture, directly and indirectly, probably supports about 1.4 billion people. In conditions where population pressure is heavy on the land, farmers in CDR agriculture often complicate and diversify their farming systems in order to raise production and reduce risk. Their consequent need for variety has not been met by standardized packages. For them, E cannot be controlled to fit G. Instead, they require a range of G - a basket of diverse choices, instead of a standardized package of practices - to enhance their ability to adapt to and exploit a varied and unpredictable E. This need has often not been reflected in the practice and outputs of agricultural science.

The next question is, what technologies does agricultural science generate for these conditions? The normal way in which agricultural science has been conducted is to generate technology on research stations and in laboratories, and then transfer it to farmers and their fields. This transfer-of-technology (TOT) mode is deeply embedded in our training and thinking. Most extensionists have been imbued with the idea that their role is to transfer technology.

The validity of this approach for CDR agriculture can be questioned. Table 2 presents contrasts between physical conditions on research experiment stations and resource-rich farms on the one hand, and resource-poor farms on the other. Table 3 similarly contrasts social and economic conditions. If most of these contrasts are true most of the time (they are not all true all the time), then it is not surprising that technology generated by scientists on research stations, in resource-rich and controlled conditions, with unlimited inputs and different priorities, is not acceptable much of the time to resource-poor farmers whose conditions differ so sharply. The TOT approach and its methods have worked up to a point in the past with industrial and green-revolution agriculture because farmers' conditions were like those of the research station, or could be made like them. The same approach does not work with the resource-poor. For rainfed farming the work of national agricultural systems, and of centres of the Consultative Group on International Agricultural Research (CGIAR) like the International Centre for Research in the Semi-Arid Tropics (ICRISAT), has led to incremental gains but no green revolution. That this should be so is scarcely surprising when one looks at these contrasts.

Table 3 Typical contrasts in social and economic conditions between research stations and farming systems

	Research experiment station	Resource-rich farmer	Resource-poor farmer
Access to purchased inputs	Unlimited, very reliable	Good, reliable	Poor, unreliable
Access to credit for inputs	Unlimited	Good	Poor, and cash seasonally short
Access to irrigation (where present)	Good - under own control	Good - own control or reliable supply	Controlled by others or less reliable
Labour supply	Unlimited, uncosted	Hired, few constraints	Family, constraining at seasonal peaks
Input prices	Irrelevant	Lower than RPF	Higher than RRF
Output prices	Irrelevant	Higher than RPF (store & sell etc.)	Lower than RRF (sale at harvest etc.)
Priority for family food production	Nil	Low	High
Extension advice	Nil	Good access	Poor access

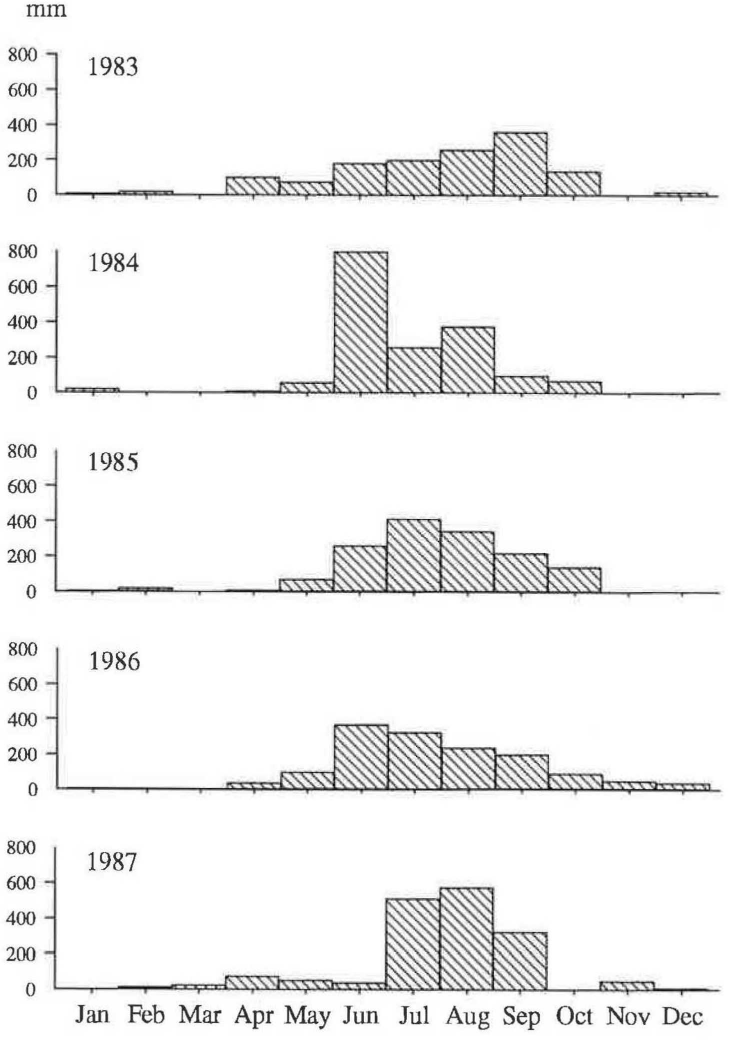


Figure 2 Monthly rainfall recorded at Hatwara District seed farm, Purulia District, India, from 1983-87

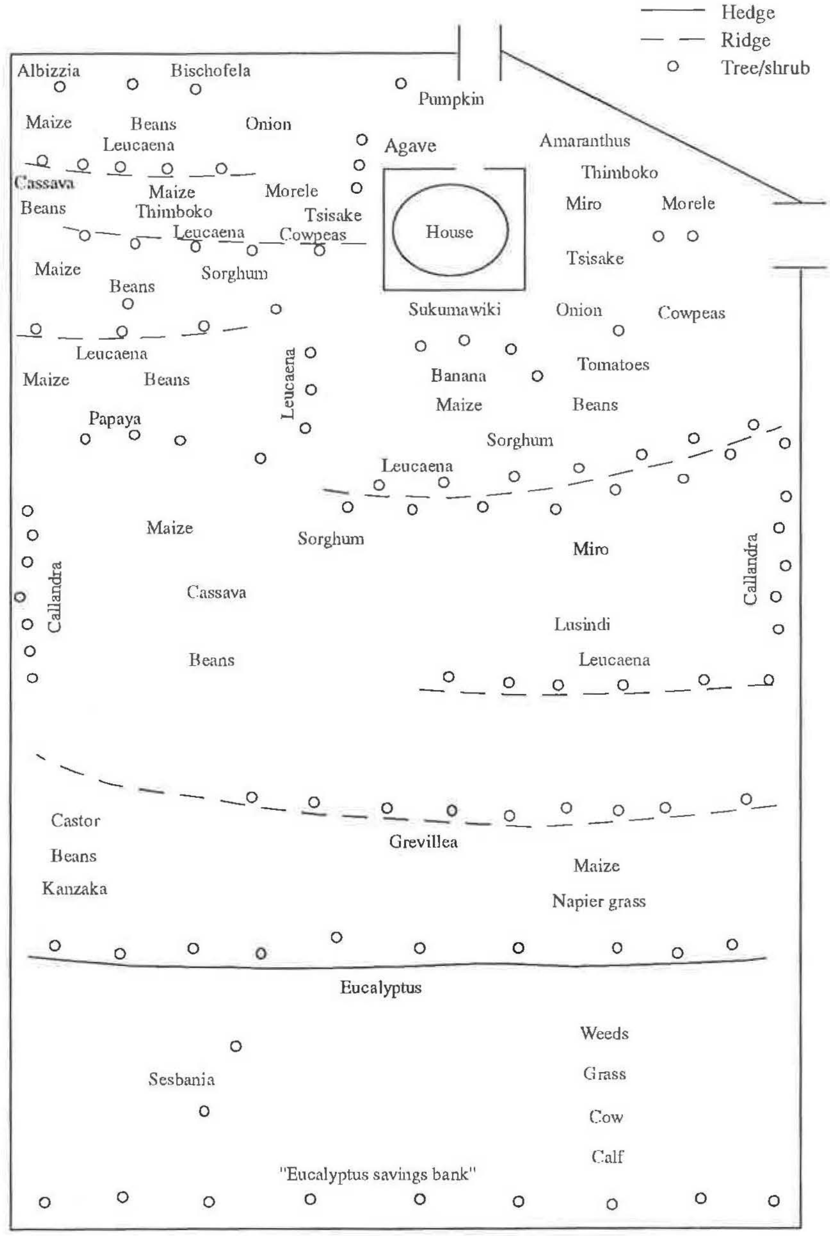


Figure 3 A farm of 0.2 ha, Kakamega, western Kenya, belonging to a family of six, with about 60 different useful species/varieties, both traditional and imported

THE RESOURCE-POOR FARMER'S POINT OF VIEW

Some sense of the uncertainty facing rainfed farmers, and their difficulty in predicting conditions, is given by Figure 2, which presents the monthly rainfall figures for a rainfall station in India over five years. For any month, one can look back on recent experience and ask what a farmer could reasonably expect in the coming month, and what decisions would be taken about planting, pest management, and so on. On the basis of the experience by the end of 1986, could better decisions be taken for 1987? Decision-making is very difficult for farmers faced with such uncertainty.

One response is to diversify. We are all familiar with the way in which farmers complicate their farming systems, adding to internal linkages. Aquaculture is a common case, often introducing several new internal linkages in a farming system. Another case is home gardens, or intensive small-scale farming. Figure 3 presents an example, a half-acre farm, on which six people live, in Kakamega District in Kenya. Gordon Conway, who sketched this in 1988, found about 60 species of useful plants were being grown. Such diversity is habitually underperceived by outsiders. A rule of thumb, on visiting a home garden, is to ask colleagues to guess how many useful species of plants will be found, and then multiply by two for an approximation of the actual number.

How do we as professionals perceive farming systems? One way of looking at knowledge is in terms of disciplines, departments and professional gaps (Figure 4). As scientists, we are trained in colleges and universities in our disciplines, and these teach us to look at the aspect of farming systems on which we specialize. We then graduate and pass into a government department which reflects that discipline. On visiting a farm, our focus of attention, the first thing we look at, is what concerns our particular discipline or department. But are there things that all our disciplines and departments habitually miss?

There are many linkages that matter in farming systems, particularly in the complex farming systems that resource-poor farmers often want but which our disciplines neglect. There is no line in Figure 4 between crops and soils because that link is well understood and has been well researched; nor does it show the household or people, who are so central to farming systems. Instead, it shows connections often overlooked or neglected by professional outsiders. For instance, the link between crops and livestock is often described in terms of 'left-overs', as crop residues; but in many farming systems, the stover, used as fodder, is a vital part of the crop and of the farming system. The same applies to other connections shown in Figure 4. And who is the expert on these internal linkages in the farming system? The answer is too obvious to state.

This raises the central question - whose knowledge counts? - a question to confront again and again. Also, whose analyses and whose priorities count? We tend to be reductionists. We like to have one criterion, such as production (or yield), but farmers as managers of complex, risk-prone systems have many criteria which they weigh up in the choice of crop varieties or the choice of pest management activities. Many examples could be given. When farmers in Colombia were asked to rank just for grain quality (Table 4), the first three were the same first three chosen by scientists, but then there were sharp differences between farmers and scientists. Again, Table 5 shows that for cassava varieties in Colombia, the yield rank and the farmers' preference rank diverged markedly. In an ICRISAT video, *Participatory Research with Women Farmers*, the women had some ten different criteria for assessing pigeon pea varieties. Again and again farmers have shown that they have not single but numerous criteria for comparing and assessing varieties of the same crop. So, whose preferences or priorities count? Those of the scientist or those of the farmer?

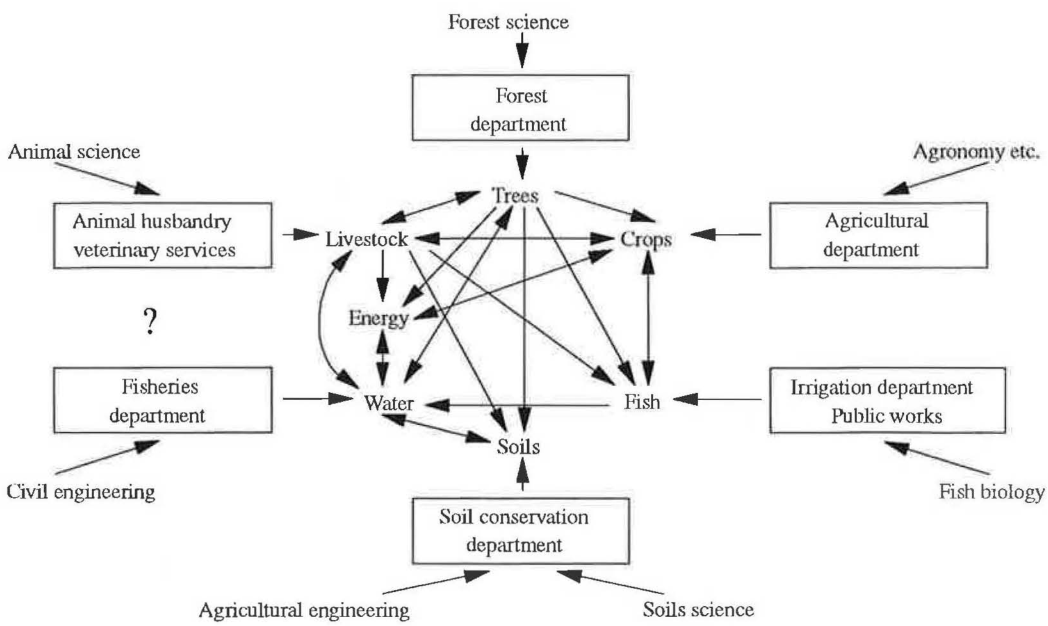


Figure 4 Disciplines, departments and professional gaps. (Appearances notwithstanding, this diagram is a gross simplification omitting as it does inputs, outputs, people, seasons etc.)

Table 4 Prescreening seed according to grain quality (source: Ashby *et al.*, 1989)

Bush bean	Grain type	Ranking	
		Farmers'	Breeders'
AFR-205	Large, purple, mottled	1	3
A-486	Large, pink, opaque	2	2
A-36	Medium, red, opaque	3	1
ANCASH-66	Medium, white	4	9
PVAD-1261	Medium, white	5	7
BAT 1297	Very small, red, opaque	6	10
G-4453TxBAT 1386 C	Small, red, opaque	7	8
HORSEHEAD XYC 206	Small, red, opaque	8	4
G7223xBAT 1276C	Small, red, opaque	9	6
ANTIOQUIA 8L-40	Small, red, opaque	10	5

Table 5 Preference rankings and yields of cassava varieties in farmer evaluation trials: harvest at 12 months, Pescador, Cauca, Colombia, 1989 (source: CIAT, 1989)

Cassava varietal material	Preference score %	Yield (nearest 1000 kg/ha)	Preference rank	Yield rank
HMC-53	100	17	1	4
76x40-3	79	23	2	1
MCOL1522	77	15	3	5
MCOL 113	75	11	4	10
CG 501-18	73	22	5	2
CG 354-2	60	11	7	9
CG 401-6	48	14	8=	7
CG 358-3	48	12	8=	8
CG 406-6	37	15	10	6

Table 6 Research and extension: beliefs and modes, 1950-2000

	Explanation of non-adoption	Prescription	Key activities	(Socio-economic) research frontier
1950s 1960s	Ignorance	Extension	Teaching	Adopters/ laggards etc.
1970s 1980s	Farm-level constraints	Remove constraints	Input supply	Constraints analysis FSR
Late 1980s 1990s...	Technology does not fit	Change the process	Farmer participation	How to enhance farmers' analysis, competence, experiments, choice. Also "our" behaviour and attitudes

Answers to these questions give further clues to reasons for non-adoption by farmers of scientists' recommendations. Historically, different reasons for non-adoption have been offered at different times (Table 6). The explanation of non-adoption given in the 1950s and 1960s was that farmers were ignorant. Extensionists, teachers and social scientists assumed that the technology was good. The main social science research questions were - who adopts, and who does not? Why are some people early adopters and some laggards? I, among others, have sinned in doing research in this (unproductive) mode.

Then in the 1970s and 1980s, people began to recognize that there were farm-level constraints. The solution was to identify and remove the constraints, to try to make the farm like the research station, to make E fit G, the green revolution approach. This led to much social science research including constraints analysis, pioneered and propagated by the International Rice Research Institute (IRRI). This aimed to identify why farmers were getting lower yields than the research station, and how important different factors were in explaining the shortfall. If E can be controlled, and production is the primary aim, this can make some sense. But if E cannot be controlled, and a risk-minimizing multiple-component livelihood is the aim, it is less useful.

In the meantime, farming systems research made a major contribution to understanding the complexity, diversity and riskiness of many farming systems, and how these explained non-adoption. But farming systems research sometimes became ponderous and lost some donor support, notably from USAID. In approach and methods, we are now moving beyond the farming systems approach to ask: who collects and analyses data, the scientist or the farmer? In the 1990s we are now aware that it is not the farmer or farm-level constraints which may be at fault, but the processes which generate the technology. If farmers do not adopt it may be because they are intelligent and sensible, not because they are stupid and ignorant. We have then to change the process that generates the technology. This is true of the social technology of IPM as well as of other technologies. The key activity becomes not input supply but farmer participation, and the real methodological frontier is how to enable farmers to do their analysis better, how to help them take command, and how to increase their confidence so that they can better adapt to changing circumstances. This approach fits well with the IPM focus.

These points are underlined from another context by Table 7. In their book *In Search of Excellence - Lessons of America's Best-Run Companies*, Peters & Waterman (1982) present this table of reasons for the non-adoption of chemical and instrument innovations in the USA. Do the same criticisms apply in agriculture?

If this analysis is more or less correct, we researchers are part of the problem: the way we have been trained; the way we are organized in bureaucracies; the way we behave. Our superior behaviour and attitudes are an impediment it is convenient to overlook. We have not been concerned much with how we behave in the field and with farmers. But by acting in a superior manner, we deter farmers from showing what they know. If it is true that the comparative advantage of farmers' knowledge is greater than once supposed, what should we do about it? Do we need to change our behaviour if we are to enable farmers to use that knowledge and do more of the analysis themselves?

The book *Farmer First: Farmer Innovation and Agricultural Research* (Chambers *et al.*, 1989) presents evidence and argument which support the idea that farmers' participation in the research process can be crucial, and that there are really two complementary approaches. One is TOT, where scientists generate

Table 7 Reasons for non-adoption of chemical and instrument innovations in USA (source: Peters & Waterman, 1982)

No enquiries of users at all	4
Too few enquiries or atypical users	6
Ignored or misinterpreted users' answers	4
No on-the-spot investigations of users' techniques	3
Committed to preconceived design	6
Total failures	23

Table 8 Transfer of technology and farmer-first compared

	TOT	FF
Main objective	Transfer technology	Empower farmers
Analysis of needs and priorities by	Outsiders	Farmers assisted by outsiders
Transferred by outsiders to farmers	Precepts Messages Package of practices	Principles Methods Basket of choices
The 'menu'	Fixed	*A la carte*
Farmers' behaviour	Act on precepts Adopt, adapt or reject package	Apply principles, use methods, choose from basket, experiment
Outsiders' desired outcomes emphasize	Widespread adoption of package	Wider choices for farmers Farmers' enhanced adaptability
Main mode of extension	Agent-to-farmer	Farmer-to-farmer
Roles of extension agent	Teacher Trainer	Facilitator, searcher for and provider of choice

the technology and it is transferred to the farmer; and the other is farmer-first, which requires many changes in the way we operate. TOT and farmer-first are not alternatives; it will always be necessary to have research stations and laboratories. But we have given these too much weight and spent too much time in them, and given too little weight to farmers' knowledge and their capacity for analysis. The objective of a farmer-first approach is to empower farmers to be able to handle their environments and gain their livelihoods better than previously. For this, as perhaps in much IPM, it is not fixed packages but principles for flexible application that we need to pass on, so that farmers can apply them through their own analysis and decision-making.

A classic example of the transfer of a principle comes from potato losses through sprouting in storage (see page 113). In Peru, researchers had been working for 20-25 years on technology for reducing losses of potatoes in storage, but with virtually no adoption by farmers. Then anthropologists from the International Potato Centre (Centro Internacional de la Papa; CIP) spent time with farmers and discovered that they did not necessarily see damage in storage as losses - some potatoes rot but are useful for feeding to pigs, and some shrivel but are a tasty delicacy. The anthropologists found that the farmers did have a problem, but it was different - that the newer potato varieties tend to sprout in storage. So scientists at CIP passed on the principle that diffused light in storage inhibits sprouting. Farmers took this principle, and applied it in innumerable different ways, very rapidly, in over 20 countries. It turned out later that the scientists had learnt this principle from farmers in Kenya: it was the farmers who had discovered it. But the main point is that it is often principles that need to be shared rather than precepts.

POTENTIAL SOLUTIONS

The two families of approaches, TOT and farmer-first, are summarized in Table 8. For IPM, it is necessary to consider whether farmers want and need principles or precepts, messages or methods, packages of practices, or baskets of choices. The approaches are further elaborated in the context of seed breeding and multiplication in Figure 5.

For farmer-first, substantial changes of role are implied on our part, as illustrated in Figure 6. The roles for outsiders are different from those in TOT. Outsiders become conveners, catalysts and consultants; we search for and supply what farmers require; we may even become travel agents and tour operators to enable farmers to go and learn from others. If IPM is working well in one area, farmers from other areas can go and learn

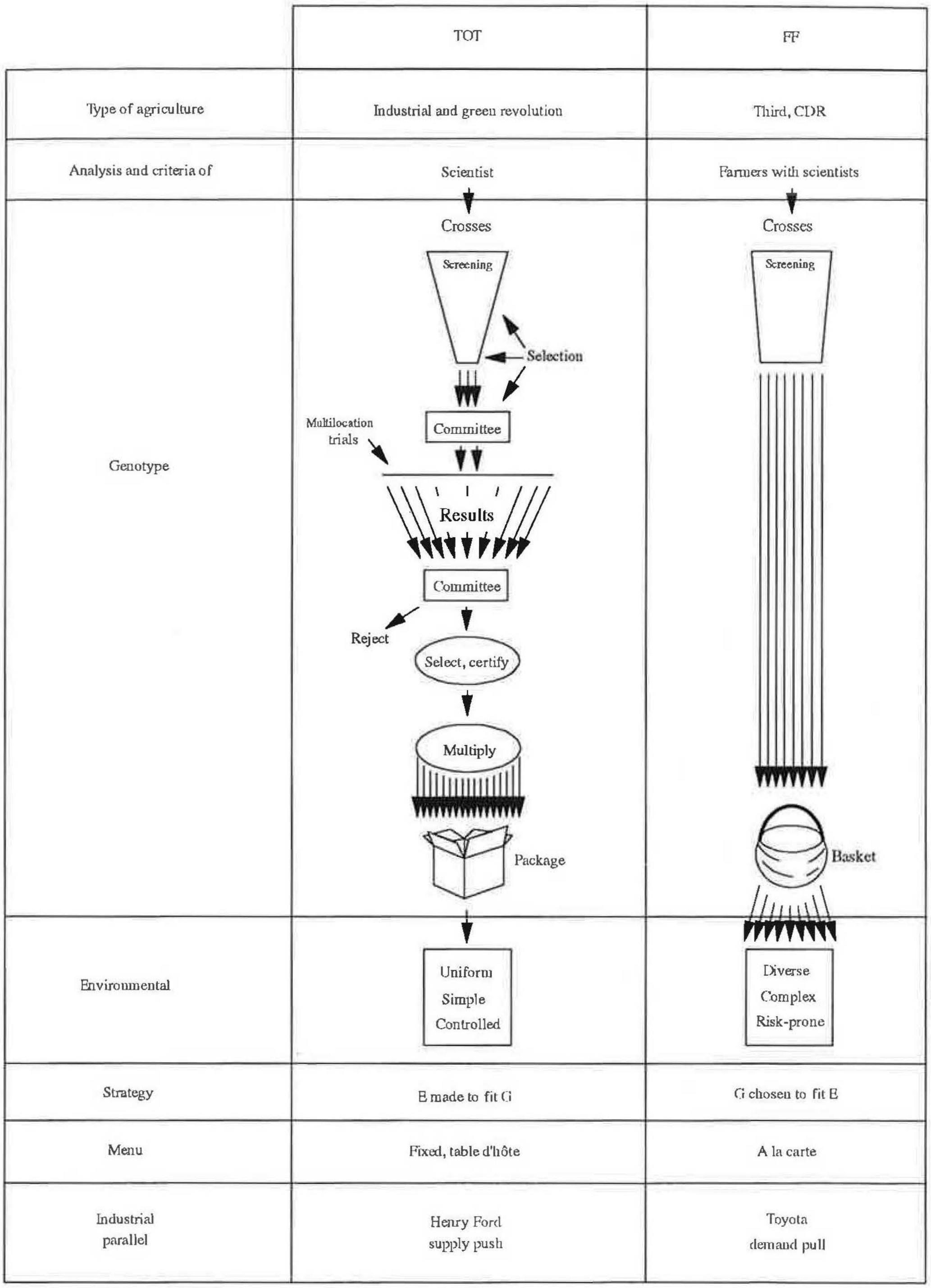
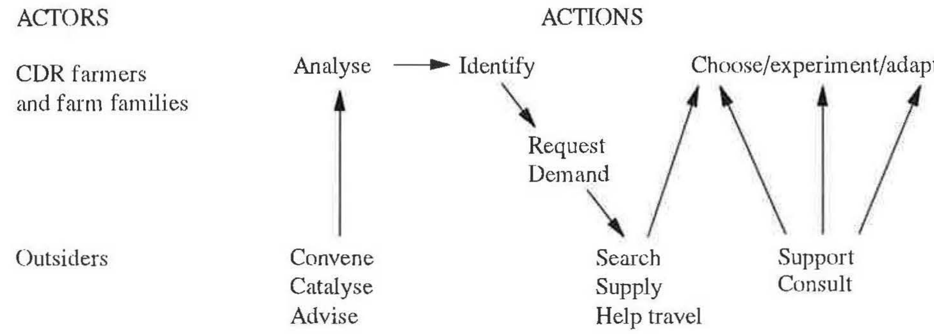


Figure 5 Strategies for breeding, selection and spread

from them - usually a more effective means of learning than if we outsiders try to start something from scratch.

We have a deeply rooted but often false idea that farmers cannot undertake the sort of analysis we know how to do. To refute this, many examples could be cited. Let a few suffice.

It has recently been found that farmers can make complex causal and flow diagrams. Some examples can be seen in the video, *Pictorial Modelling: a Farmer-Participatory Method for Modelling Bioresource Flows in Farming Systems*, produced by the International Center for Living Aquatic Resources Management



The processes are iterative
Roles: Convenor
Catalyst and consultant
Searcher and supplier
Travel agent and tour operator

Figure 6 Farmers' analysis-choice-experiment

(ICLARM), of Malawian farmers drawing diagrams on the ground of nutrient flows on their farms.

Another example is shown in Figure 7, the analysis presented by an old man in a risk-prone farming area in the semi-arid tropics in India. We asked him about changes in agriculture since India's independence in 1947, and he started to draw on the ground what had been happening to farming in that area, including declining soil fertility and increasing incidence of pests.

A farmer in Gujurat, India, the secretary of a co-operative, was asked about the impact of irrigation in his village. Normally with a question like that, we would draw up a list, prepare a questionnaire, and interview people using our questions. But who are the experts on the impact of irrigation? Figure 8 shows the diagram the farmer drew in about 20-25 minutes, with some assistance from his colleagues. It shows water flows, complex interactions in the fields, outputs, including food and money, the impact on different trees, and a positive impact on the school (which is something we might not have thought to ask about).

Interestingly, the ability to diagram like this appears to be independent of literacy. Indeed, farmers' diagrams of their farming systems can be more detailed and informative than those made by scientists.

Much the same has been shown with estimating and ranking. Figure 9 shows one of a group of women near

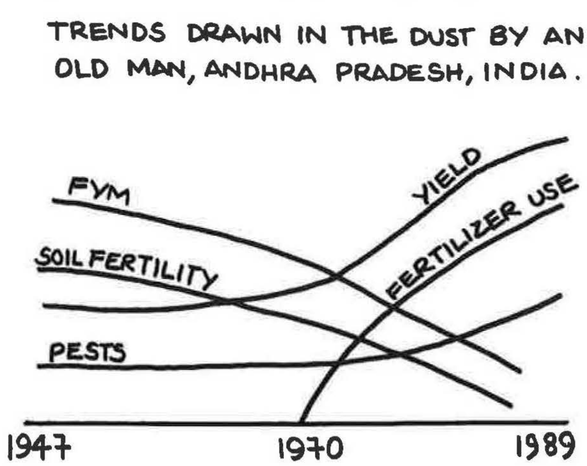


Figure 7 Diagram of the changes since India's independence drawn on the ground by an old farmer in Mahbubnagar District, India, as subsequently copied out

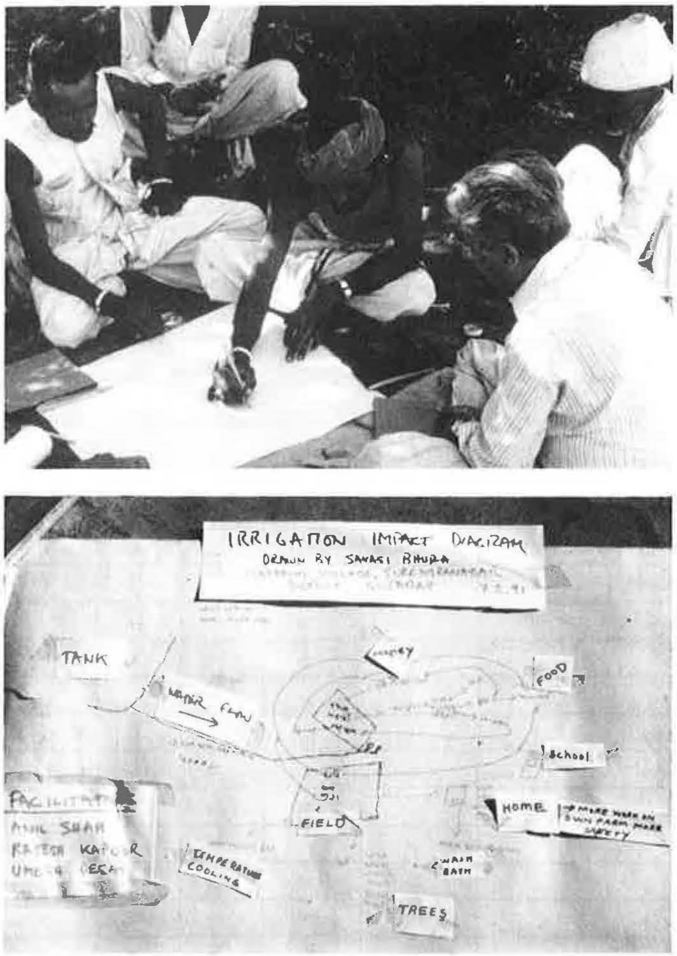


Figure 8 Top, a farmer in Surendranagar District, Gujurat, diagramming the impact of irrigation: below, the diagram he drew in about 20-25 minutes

Marangu in Tanzania undertaking matrix scoring for six varieties of banana. First, they named 14 varieties which they grew, and then selected the six most important. They then named seven ways in which these varieties were prepared and consumed, such as frying, and pombe (beer). Then they used maize seeds to score the varieties for each of the seven uses. Later, when men and women were asked to rank the varieties, there was one difference (usually there are several): the men gave the main variety for pombe a higher rating. The lesson here is to disaggregate between groups of people - between resource-rich and resource-poor, between women and men, in making rankings and estimates.

Figure 10 shows the matrix devised by an Indian farmer to distinguish the characteristics of six varieties of millet. Visual diagramming by farmers like these provides a means to express and enhance their own analysis, and also present an agenda for discussion. It can be vital for farmers to have time to discuss questions on their own, without outsiders present. Farmers, like others, enjoy and need iterative discussions without being rushed, while our tendency has been to hurry and hustle.

Not just for their learning but especially for ours, diagrams made by farmers are useful. They can be 'interviewed'. Important questions may be identified through the act of diagramming. Multiple criteria can be weighed. In the ICRISAT video, for example, after the use of a matrix on the ground to compare varieties of pigeon pea, one ICRISAT and one Government release were rejected by the women, even though they were more pest-resistant than some others, because the balance of other criteria was more important. As with seed breeding, so with IPM, there may be many applications of new approaches and methods such as these.

Mishiri village near marangu, Tanzania.

	Varieties of banana					
Modes of preparation	Irongwoe	Mchare	Ndishi	Kitoke	Ki-sukari	Mbwee
Machalari	4	29	-	9	-	-
Muturi	25	9	-	22	-	-
Kibure	-	27	-	-	-	-
Kitawa	-	33	-	-	-	16
Kukaanga	-	17	-	-	-	16
Kuchoma	28	12	6	-	-	17
Mrivu	9	18	8	7	28	13
Pombe	24	-	37	7	25	free
Wengi	22	32	18	7	9	6
Shilingi	400	500	400	300	200	-
Woman's preference	2	1	4	3	5	6
Men's preference	2	1	3	4	5	6

Scored with maize seeds on the ground.
Analysts: Felista Mfuru, Eva Machaio, Veronica Machaio, Rogate Makombe, Naiuyi Makombe, Hoita Makombe, Alice Malimo, Eliangiendiosa Makale.

Figure 9 Top, matrix scoring of six varieties of banana by women near Marangu, Kilimanjaro, June 1991; below, the matrix as copied on paper

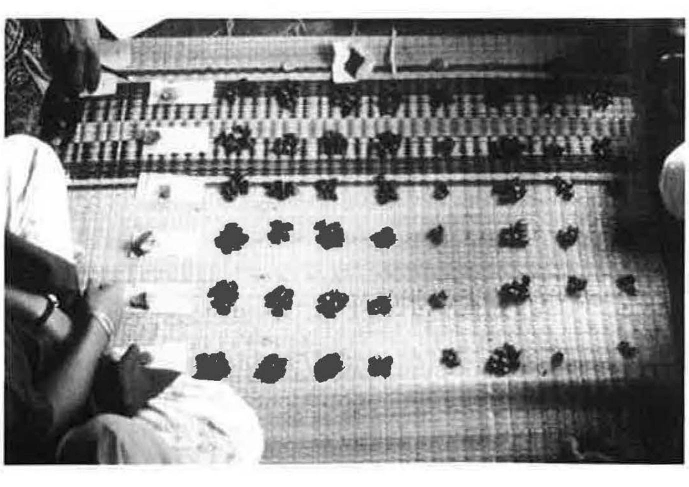


Figure 10 Matrix scoring by a farmer, according to his criteria, for six varieties of millet, at Nugudam, Karnataka, India, facilitated by Vidya Ramachandran of MYRADA

QUESTIONS

Finally, in the light of all this, there are three questions for this conference.

The first is: *whose knowledge counts?* (Figure 1). Does the scientist's knowledge count too much? Are we too dominant? Does the farmer's knowledge often not count enough? What are the comparative advantages of their knowledge and experience, and of ours? Where do we know better, and where do they know better? How can the two sets of knowledge best be combined? In any process of analysis, is the farmer's knowledge enhanced? Does she or he take command?

The second is: *who chooses?* Do we choose packages for farmers or do we present them with baskets from which they can choose? There is a question of balance here. It may be that for IPM the word 'package' and what it represents makes some sense, but in general, is a package the right approach or is a 'basket' better, where researchers suggest various options that farmers can take, and ask which they feel makes sense to them?

The third is: *who gains?* Of traders, resource-rich farmers, resource-poor farmers, consumers and scientists, who actually benefits? And especially *which farmers*, with questions of gender and poverty fundamental. Does the process in which we are involved with farmers lead them to gain in competence and adaptability?

The central issue we have to face is whether farmers are being empowered so that they can handle things better themselves, or whether it is scientists who are being empowered. The professional challenge to us is to stand down off our professional pedestals; to see whether through our efforts, it can be the farmers who are empowered; and to enable them to adapt and manage better in the uncertain and risk-prone environments in which so many of them have to struggle for their livelihoods.

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KEYNOTE ADDRESS

Crop protection strategies - their status with resource-poor farmers

T. SENGOOBA

Namulonge Research Station, PO Box 7084, Kampala, Uganda

ABSTRACT

Farmers are vital to the economies of developing countries, yet the yields they produce are low. Small-scale farmers may be unable to invest in machinery, seeds and other inputs, or to use intensive farming methods. Farmers suffer from a lack of land, with associated pest management problems such as the inability to practise crop rotation, and intense inoculum pressure at the margins of small fields. Also, even farmers of cash crops have little influence on market prices. There is a need for crop protection measures which are cheap, simple, cost-effective and sustainable. Appropriate strategies include the use of resistant cultivars, pest forecasting, biological control, pest exclusion through quarantine, and cultural and chemical control. These are already being used in combination, but improved packages are needed. It is recommended that economic thresholds for all major pests of food and cash crops should be established and crop protection researchers must develop pest control strategies specifically suited to resource-poor farmers.

RESUME

Les paysans sont essentiels aux économies des pays en développement et pourtant leurs rendements sont faibles. Les petits exploitants peuvent ne pas avoir les moyens d'investir en machines agricoles, en semences et autres intrants ou d'utiliser des méthodes de culture intensive. Les paysans souffrent d'une pénurie de terres et des problèmes de lutte contre les fléaux qui y sont associés comme, par exemple, l'incapacité de pratiquer une rotation des cultures et la pression intense d'inoculant qui existe en bordure des champs de petite taille. En outre, même les producteurs de cultures de rente ont peu d'influence sur les prix du marché. Des mesures de protection des cultures qui soient bon marché, simples, d'un bon rapport coût-utilité et qui soient durables s'imposent. Des stratégies appropriées incluent l'utilisation de cultivars résistants, la prévision des fléaux, la lutte biologique, l'exclusion des fléaux grâce à la mise en quarantaine ainsi que la lutte culturale et chimique. Ces mesures sont déjà utilisées de façon combinée mais des programmes globaux améliorés sont nécessaires. Il est recommandé d'établir des seuils économiques pour tous les fléaux majeurs des cultures vivrières et de rente et les chercheurs dans le domaine de la protection des cultures devraient mettre au point des stratégies de lutte contre les fléaux, qui conviennent spécifiquement aux paysans disposant de peu de ressources.

INTRODUCTION

The title for this seminar is *Crop Protection for Resource-Poor Farmers*. I take 'resource-poor farmers' to be mainly the small-scale farmers from the developing countries; 'pest' in this paper is taken to mean both insect pests and disease-causing pathogens.

According to the Food and Agriculture Organization of the United Nations (FAO, 1989) an estimated 50% of the world population is engaged in agriculture. If this is broken down, well over 50% of the people in the developing countries, in which agriculture is important, are involved in agricultural activities while often less than 10% of the people in the developed world are engaged in agriculture. Table 1 gives figures of populations and the percentage engaged in agriculture in some selected regions of the world. It is interesting to note that whereas over 30 million people in Africa practise agriculture, only about 90 million are involved in agriculture in both Europe and North America. So this conference addresses by far the majority of the world's farmers.

RESOURCE-POOR FARMERS

In many developing countries, the resource-poor farmers have to produce and sustain the economy. They have to produce enough food for their people and a surplus for export. They have to produce cash crops for

Table 1 World population in agriculture

Region	Population (x 000)	Percentage in agriculture
World	5 200 000	50
Africa	600 000	65
North America	420 000	11
South America	300 000	23
Asia	3 000 000	60
Europe	500 000	10
Oceania	260 000	17
USA	250 000	2.5
Canada	260 000	3.5
UK	57 000	2
Burundi	8 700	91
Malawi	11 600	76
Cameroon	10 900	62
Ethiopia	45 700	75
Kenya	18 600	77
Uganda	17 800	81

Source: FAO (1989)

local industries or for export. A country like Uganda gains over 90% of its foreign exchange earnings from agricultural products.

The crop yields of resource-poor farmers are much lower than those recorded in the developed world. Table 2 gives some figures which clearly indicate that, with a few exceptions, yields are higher in North America and Europe than in Africa and South America. A major reason for these poor yields is pests and diseases, estimated to cause 20-30% of crop losses in the developing world.

These resource-poor farmers are craving for higher yields from their crops. Surveys among such farmers reveal that they wish to obtain high-yielding genotypes and high productivity packages in general. These farmers are very receptive to improved production packages.

THE PROBLEMS OF RESOURCE-POOR FARMERS

The problems facing the small-scale or resource-poor farmer in the world today are complex.

* Resource-poor farmers have no money to invest in modern, cost-effective technologies for crop production in general or crop protection in particular. At times even small items like spray pumps may not be within the scope of such a farmer. Improved seeds must have great advantages before a poor farmer can sacrifice money to buy them.

* The resource-poor farmer has very little land, in most cases less than 5 ha, and he/she has to subsist on it. At times the limits on land make it difficult to adopt some pest control strategies. For example, farmers may not be in a position to adopt crop rotation if they are also to feed their families.

* From a crop protection perspective, resource-poor farmers have some unique problems because of their small fields; for example, the inoculum from neighbouring crops is often abundant and there is generally much spread of inoculum between fields.

* Due to limited labour and funds, the resource-poor farmer cannot exploit intensive farming methods.

* The governments of some resource-poor farmers have attempted to help them by introducing

mechanization on a communal basis. This has not worked well, basically due to management problems.

* Mechanization, if it is to work properly, should be used at almost all stages in the production process. This is not the case for resource-poor farmers who may, for example, get a tractor to open up a 'large' piece of land and yet have to weed by hand and use human labour for crop protection activities.

* In the case of cash crops the resource-poor people play no role in pricing their commodities, both within and in particular outside their countries, which perpetuates their poverty.

Resource-poor farmers therefore require crop protection measures that are:

* cheap, so that farmers can afford them

* simple, so that they can be applied under particular circumstances

* cost-effective, so that they can enable farmers to make profits and prosper

* sustainable, so that the production is also sustained.

The different crop protection strategies have been explored at various levels and their status is worth reviewing.

CROP PROTECTION STRATEGIES

Resistant varieties

Use of resistant varieties is one of the most applicable, low-cost and attractive pest control technologies for resource-poor farmers. Governments and even private sectors invest heavily in this technology, and the output has been most encouraging. There are numerous examples where resistant varieties have contributed significantly to increased productivity. However, both the reliability and availability of resistance are often very variable factors. Also, the process of producing resistant varieties through research is often quite slow and laborious. Farmers in the developing world today continue to grow genotypes which are susceptible to pests. In some cases this is because no resistant genotypes are known, but also farmers may stick to the susceptible genotype because it has other popular or preferred characteristics, e.g. colour, taste, early maturity. The advantages of hybrids have been little exploited by resource-poor farmers because they may not afford or have access to the new seeds available each cropping season.

Biological control

Biological control is a sustainable solution to crop pest problems. The Chinese controlled insect pest densities by exploiting natural enemies and by adjusting planting dates several centuries before the birth of

Table 2 Crop yields in selected zones of the world (kg/ha)

Crop	World	Africa	N. America	S. America	Asia	Europe
Cereals	2 646	1 228	3 627	2 079	2 686	4 246
Maize	3 627	1 742	5 412	2 096	2 086	5 219
Rice	3 457	1 899	5 098	5 707	3 539	5 138
Potatoes	15 315	8 634	28 352	12 560	13 330	21 502
Beans	588	676	837	518	538	631

Source: FAO (1989)

Christ (Wilson, 1988). Biological control has several advantages: at its best it is sustainable, inexpensive, and presents no health hazards or environmental pollution. Biological control could be regarded as a high-risk investment, but the pay-off is so great when positive results are obtained that this field should continue to attract attention. There are several successful programmes of biological control in the developing world. For example, the control of cassava mealybug has been achieved through biological control (IITA, 1990; see page 45), and similar successes in controlling the cassava mite and cassava mosaic virus would, if possible, be of great value.

The major shortcoming of biological control is that lengthy, detailed ecological studies have to be done before a successful package can be developed. At the moment it would appear that biological control is applicable to a rather narrow range of pests, mainly insect pests.

Plant quarantine

Plant quarantine plays a major role in crop protection by eliminating particular pests from certain regions. Unfortunately plant quarantine cannot and has not provided 100% protection from foreign pests. Many pests have been known to be introduced due to lack of proper quarantine regulations or practices. Pests that have been introduced in eastern Africa include the cassava green mite which was introduced from Latin America; black sigatoka of bananas which was introduced from the West Indies; and the larger grain borer.

Plant quarantine is a vital service for resource-poor farmers. When pests become established in farming systems they can be difficult to control and expensive, both directly and indirectly, to the farmers. Support for establishing proper plant quarantine services is of great value to farmers in the developing countries of the tropics.

Cultural control

Cultural controls are usually the most inexpensive control measures. They include:

* destruction of plant residues after harvest
* crop rotation
* rogueing of infected plants from a crop and their destruction
* closed planting seasons
* planting 'early', at a stage of low inoculum pressure
* sorting seed and planting only clean seed
* weeding
* intercropping of different species
* mixed cropping of different genotypes.

Examples of the above cultural control practices are normally within the traditional crop production measures practised by small-scale farmers. Although these cultural control measures may result in reduction of crop pests and diseases, other factors in farming may limit their effectiveness. For example, resource-poor farmers may not be able to plant their crops all at the same time; those crops planted later may suffer from abundant inoculum from the earlier plantings, which offsets the effects of cultural control measures. In reality, cultural control measures by themselves rarely achieve very high levels of control, especially on a small-scale farm.

In certain cases physical control measures may be employed, such as picking off insects or laying traps. However, on a small farm scale the success of such measures will depend on all growers of the crop concerned within an area co-ordinating the practice of a particular control measure. For students of crop protection, cultural control measures should be valued for their additive contribution to pest control as a whole, and improved possibly through community-based control strategies.

Chemical control

Pest problems and pest control are by no means peculiar to modern agriculture. It is well known that some 5000 years ago, well before 2500 B.C., the Sumerians used sulphur compounds to control insects and mites, and around 3000-2500 B.C. crude wooden implements were used to control weeds. The first-formulated pesticides included DDT in the 1940s and Bordeaux mixtures in the 1950s. After the Second World War there was an explosion in the use of chemicals for pest control. This era brought about great improvements in crop production which resulted in the green revolution.

Chemical pesticides are in general popular with farmers because of their quick, effective action. Farmers in the developing countries are at this stage in development becoming more and more interested in using chemicals for control. However, it is presently accepted that the risks to human lives and to the environment are so great that there is no longer any question about the necessity for changing to crop protection techniques which are less dependent on chemicals. In 1983, there were two million cases of poisoning by pesticides, 40 000 of which were fatal. Probably the numbers are on the increase as the levels of pesticide use are also increasing (Schoubroeck *et al.*, 1989). Uganda has had its share of problems caused by overuse of chemicals: dieldrin was used for a long time to control the banana weevil, which acquired resistance and built up to epidemic levels, and resulted in very severe destruction of the banana plantations. It is important that research efforts in the developing world should be directed to selective use of pesticides at reduced dosages and frequencies. This will reduce the development of pest resistance, environmental hazards, user poisoning and elimination of non-target organisms.

The research scientist is the person who knows more about the hazardous effects of the use of pesticides, and is therefore the person who should face the challenge not only to convince farmers about the bad effects of chemicals, but also to offer them an effective alternative for pest control. Do we have an effective pest control strategy that can match the use of chemical pesticides?

Integrated pest management (IPM)

IPM is a pest control strategy that been around for some time, albeit unrecognized. The IPM strategy was first highlighted in the mid 1960s following the campaign of Carson against dependency on chemical insecticides at the expense of biological control; it is the popular pest control strategy today and is seen as offering salvation from overdependency on chemicals. Definitions of IPM have been suggested by several workers, but Dickson & Lucas (1977) state that IPM involves the creation of systems which utilize all available methods in as compatible a manner as possible, so as to maintain a pathogen population at a level below that which would cause economic loss. Wilson (1990) describes IPM as "a multi-disciplinary approach to crop protection, where all available methods of reducing the pest population on a given crop production system are integrated to achieve optimum economic benefit with minimal ecological impact on the environment". IPM is a crop protection package with a number of components and has the advantage that the package can be enriched gradually while already in use.

The concept of IPM may vary from community to community. It has been stated that IPM was developed for high-input systems in developed countries to counteract the negative effect of excessive use of chemicals. In this context it has been indicated that for the poor farmers of the developing countries, integrated crop management may be a better approach than IPM. It should be emphasized that for the resource-poor farmers, the question is not overuse of pesticides, but their misuse and underuse. The issue cannot be overlooked by resource-poor farmers, particularly when opportunities arise of markets in the developed world, where products treated with chemicals are least acceptable.

What are resource-poor farmers doing to protect their crops today? Farmers are using cultural control measures; using improved, pest resistant genotypes where they are available; and in a few instances using chemicals. Chemical control is employed where it is absolutely necessary, when it is economically viable and where or when the farmer can afford the technology. For example, in Uganda insecticides are used on cotton to control the various pests. This makes cotton production sophisticated and expensive, and some farmers have abandoned it for this reason. Farmers use fungicides for control of late blight on tomatoes and potatoes when grown for the urban market.

In all these cases, chemical control measures are used in addition to cultural methods such as variable planting times, crop rotation and pruning. The farmers are already using the IPM strategy, and the challenge to crop protection researchers is to improve the available IPM packages to achieve effective control of pests and attain economic advantages.

Pest forecasting

Forecasting is an advanced and specialized control strategy which may be vital for particular pests and diseases. Forecasting is a component of IPM and in Africa it is used on a large scale for the control of locusts and armyworms. It is necessary to develop and utilize cheaper means of forecasting in the case of other pests. For example, pests like beanfly in Africa and the leafhopper vectors of maize streak virus have a very varied occurrence between seasons. Proper forecasting could greatly assist in developing a control strategy for these pests.

RECOMMENDATIONS

The aspect of economic threshold levels is under-researched in many developing countries. A few instances do exist for pests of major cash crops such as coffee and cotton which have been worked on for a long time. There is a need to evolve and establish economic threshold levels on all major pests of food and cash crops in order to facilitate the utilization of monitoring information and guide decisions on research priorities.

Crop protection researchers should develop pest control strategies for use by resource-poor farmers. These control measures must therefore address farmers' perceived problems, needs and opportunities, as identified by research officers working closely with extension staff and farmers, and based on scientific diagnostic reviews of problems and constraints. Such reviews should include yield losses due to the pests under study in the farmers' environment.

The crop protection technologies that are developed for utilization by resource-poor farmers should be feasible, socially acceptable, environmentally sustainable and, above all, economically beneficial to the farmers.

The farm structure and the farming communities should be borne in mind when deriving recommendations, and where appropriate a community-based control strategy should be advocated.

ACKNOWLEDGEMENTS

I wish to thank the organizers of this workshop for inviting me, and for giving me the opportunity to make this presentation. I am also very grateful to CTA for their financial support which has enabled me to attend the workshop.

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IPM in the Sahelian zone, peasant-level farm environment of north-west Mali

N. D. JAGO

Natural Resources Institute, Central Avenue, Chatham Maritime, Chatham, Kent ME4 4TB, UK

ABSTRACT

The world's biggest millet-producing ecozone lies in a tract of Africa which extends from Senegal to Somalia, south of the Sahara. Mean annual rainfall ranges from 300-500 mm/year. Major constraints to millet (*Pennisetum glaucum*) and sorghum production are experienced, including those related to erratic rainfall and a suite of crop pests. The pests include grasshoppers (eight spp.), millet head miner (*Heliocheilus albipunctella*), meloid beetles (including *Psalydolytta* spp.), millet stem borer (*Coniesta ignefusalis*) and cetoniine beetles (*Pachnoda interrupta*). The threat from each of these component pests varies from year to year. Farmer practice aims at minimizing the risk with minimal investment input. Average family investment is F.CFA 500/ha/year, but this figure is based on investment by only 20-30% of families. The market value of millet lies between F.CFA 45 and 150/kg, according to availability. Self-financing pest management must therefore be very cheap to achieve a benefit:cost ratio of 2:1. A ceiling of F.CFA 6500/ha/year (roughly £10 sterling) investment, accompanied by a crop-loss reduction of 140 kg/ha, are the criteria necessary for success. There is the hope that this will occur, given that the inputs tested during the ODA/NRI project are tried in whole pilot villages, rather than on an individual pilot farmer test-plot basis. Integrated pest management (IPM) still assumes minimal chemical pesticide intervention, made feasible with newly designed, low-cost, ultra-low-volume (ULV) equipment, coupled with the use of simple dusting techniques for applying pesticide and improved attention to current agronomic practices.

RESUME

La plus grande zone de production du mil dans le monde se trouve en Afrique dans une bande qui s'étend du Sénégal à la Somalie, au sud du Sahara. La pluviométrie annuelle moyenne y est de 300 à 500 mm/an. Des contraintes majeures à la production de mil (*Pennisetum glaucum*) et de sorgho existent et incluent les limitations relatives à la pluviométrie irrégulière et à une succession de fléaux. Les fléaux incluent les sauterelles (huit espèces), le mineur des épis de mil (*Heliocheilus albipunctella*), les cantharides (comprenant *Psalydolytta* spp.), le déprédateur des tiges du mil (*Coniesta ignefusalis*) et *Pachnoda interrupta*. La menace que représente chacun de ces fléaux varie d'une année à l'autre. Les paysans cherchent à minimiser les risques grâce à un investissement minimum en intrants. L'investissement moyen d'une famille est de 500 F.CFA/ha/an mais ce chiffre est basé sur l'investissement effectué par 20 à 30% seulement des familles. La valeur marchande du mil va de 45 F.CFA à 150 F.CFA/kg selon la disponibilité. La lutte intégrée et autofinancée contre les fléaux doit, par conséquent, être très bon marché afin d'arriver à un rapport coût-utilité de 2:1. Un plafond de 6500 F.CFA d'investissement par ha et par an (environ 10 livres sterling), accompagné d'une réduction des pertes culturales de 140 kg/ha sont les critères nécessaires au succès. Nous espérons que cet espoir verra le jour, étant donné que les intrants testés au cours du projet ODA/NRI font l'objet d'essais au niveau de l'ensemble des villages pilotes plutôt que sur la base de parcelles d'essais appartenant individuellement à des agriculteurs pilotes. La lutte intégrée contre les fléaux suppose toujours une intervention minime en pesticides chimiques, rendue possible grâce à un équipement d'ultra-pulvérisation bon marché, récemment mis au point, auquel on associe l'utilisation de techniques simples d'application de pesticide par empoussiérage et une plus grande attention aux pratiques agronomiques actuelles.

INTRODUCTION

The Natural Resources Institute (NRI) and its predecessor organizations came into the Sahel thanks to the Service National de Protection des Vegetaux (SNPV), Mali, principally to carry out a plant protection exercise and, over a period of six years, we have educated ourselves into the integrated pest management (IPM) approach to crop protection. In spite of their limited resources, the Sahelian farmers are already using integrated crop management. For example, pesticides are a very low priority amongst these farmers. They select the best plant varieties, apply organic manure, and weed as well as possible with the available labour, which can be a limiting factor. Farmers spread risk by staggering sowing times, intercropping with various crop species, and planting long- and short-cycle varieties. Farmers also respond very rapidly to the onset of rainfall and pest attacks during the season, and may for example plough up millet and replace it with sorghum. Conditions in the Sahel are extremely difficult and farmers' survival there often seems miraculous.

The agricultural system involves few inputs and our role must be limited. However, there are weaknesses amongst the farmers with which we can help. We can help farmers not to underestimate the importance of 'invisible' pests and pathogens, help them to predict the danger of pest outbreaks and, to a certain extent, forecast low rainfall. However, it is only in a few cases that we are better at this than the farmers. In the near future I think one of our major opportunities to assist the Sahelian farmers will come from remote sensing techniques, through which we will be able to forecast rainfall at least in the near-distant future. With a better knowledge of pest biology, we will be able to improve the timing of farmers' inputs into IPM, and expand practical crop-loss assessment techniques, which are essential to justify the inputs that are required by IPM. Underpinning it all, we need to introduce economic analysis of IPM.

AGRONOMY

The average farming unit in north-west Mali is a family of about 15 people. They require 5 ha of cultivated land, with an output of about 500 kg/ha, to be self-sufficient in a year. The donkey cart and the plough have made it possible to introduce certain other advances into the IPM programme. For example, unless sowing is carried out in lines, using a plough to create ridge and furrow, it is not possible to introduce low-volume liquid pesticides, because later on in the year you would get lost in the millet field. The plough is drawn in Mali by animal traction; horses are faster, but the farmers have taught us that it takes a quarter of a hectare of millet to feed a horse, so although oxen are slower they are often preferred to the horse. There are two types of field in the project area, the bush field, which is returned to fallow every two or three years and has very low manuring; and the 'village field', which is highly manured and cultivated more or less continuously. These two groups of fields have broadly different pest management problems.

PESTS

The importance of each species of grasshopper pest varies from year to year. In 1986 farmers at Mourdiah lost 25% of seedling area to early season attack by the Senegalese locust (*Oedaleus senegalensis*) but escaped in 1987-89. Following the favourable rains of 1988 and the equally good rains of 1989, an explosive increase in seven grasshopper species caused 10-16% mid- and late-season losses of millet in the Mourdiah area and 30-40% crop-loss in the Nara/Dilli area. Damage by grasshopper pests involves loss of planted area, defoliation and damage to grain on the candle at the milky stage. All adult Sahelian grasshopper pests are capable of large displacements (up to 200 km/night), hence constant monitoring is an essential part of IPM.

The millet candle miner moth (*Heliocheilus albipunctella*) has a single generation per year. The moths lay at night on the newly emerged candles and the larval damage is at first invisible, but 'mines' later appear, often leading to the total destruction of the candle. Crop losses may be 40-60% (as in 1984-85) but have diminished since 1989. In years of good rainfall millet can compensate for the damage.

The millet stem borer (*Coniesta ignefusalis*) has two generations per year in the Nara region. Until 1989 about 30% of stems were attacked in the Nara-Dilli belt, but only 10-15% at Mourdiah. There has been a sudden increase in 1990. The grain loss caused, however, is probably economically unimportant, and the method of control with expensive granule-formulation pesticides uneconomic. Even if 100% of the stems in a millet field are attacked, farmers should not be panicked into using extremely expensive granular pesticides, which in any case are not very effective against stem borer. The larvae of meloid beetles (three species of *Psalydolytta*) are probably parasites in the egg pods of grasshoppers. As adults they feed by night and day on the millet flowers, causing sterilization of the florets. In 1990 they caused 40-50% crop loss in the Mourdiah area, high numbers following the year of high grasshopper numbers.

CONTROL

The cycle of millet growth throughout the year has certain critical periods for pest control. At the beginning of the growing season, in June, the major pests are the grasshoppers which, gaining access to the fields, can destroy the seedlings. However the economic consequences of this crop loss are not very serious to the farmer. In 1986, as much as 25% of the field area was lost to early season grasshopper damage, but the farmers told us that this was not a major crisis because they had not invested their money and labour in the crop at this stage, and could divert their resources to other crops on their farms.

During July, the crop is relatively unaffected by pests because it is growing faster than it can be eaten. We have discovered that up to 50% of the leaves can be removed before there is an effect on the millet candle. One of the important lessons in IPM is to know when not to treat, rather than when to treat.

The next important period is the emergence of the millet candle and flowering: at this stage a major crop loss may start to develop due to beetles attacking the flowering candles and the millet head miner mining the candle. The damage caused is not immediately apparent but is later very evident. Curiously, despite these levels of damage, the farmers have not recognized this as a major pest. They are much more inclined to deal with pests that cause visible damage to the crop, rather than those which have to be treated well in advance of the appearance of damage. At the end of the year, just before harvest, is the final damage, mainly caused by grasshoppers feeding on the milky grains.

The most important pests are the grasshopper complex. Many of these pest species are highly mobile, and to speak of regional reduction in populations is senseless - what we must look at is local crop protection. Several of the species may be found together; Figure 1 shows three commonly seen species. The farmers grow a mixture of sorghum and millet. The intercropping of sorghum, which takes place particularly in the village fields, often gives very clear evidence that grasshoppers prefer millet to sorghum. Figure 2 shows a farmer who has attempted to prevent the entry of grasshoppers by planting a margin of sorghum, which is repellent to the grasshoppers.

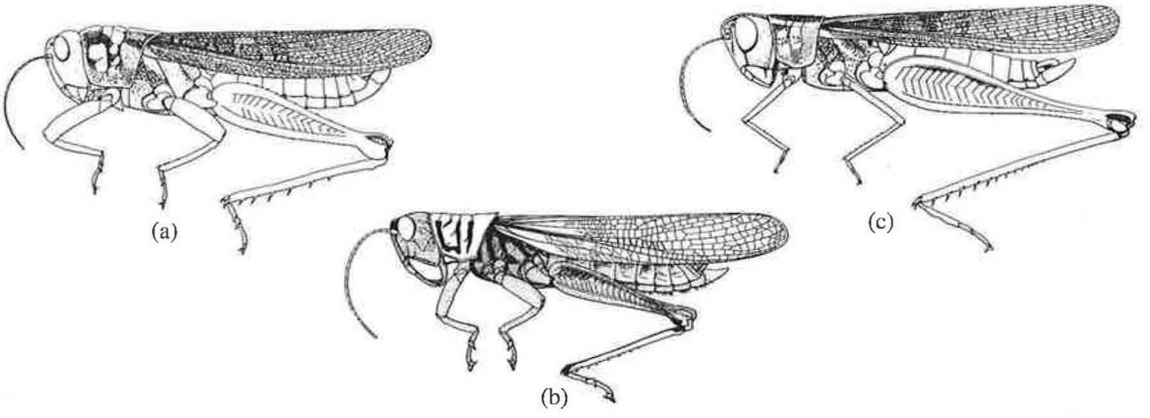

Figure 1 (a) *Kraussaria angulifera*; (b) *Hieroglyphus daganensis*; (c) *Cataloipus oberthuri*. (From Dirsh, V. M. (1965) *The African Genera of Acridoidea*. Cambridge: Cambridge University Press.)

Figure 2 A margin of sorghum gives a field of millet some protection against grasshoppers

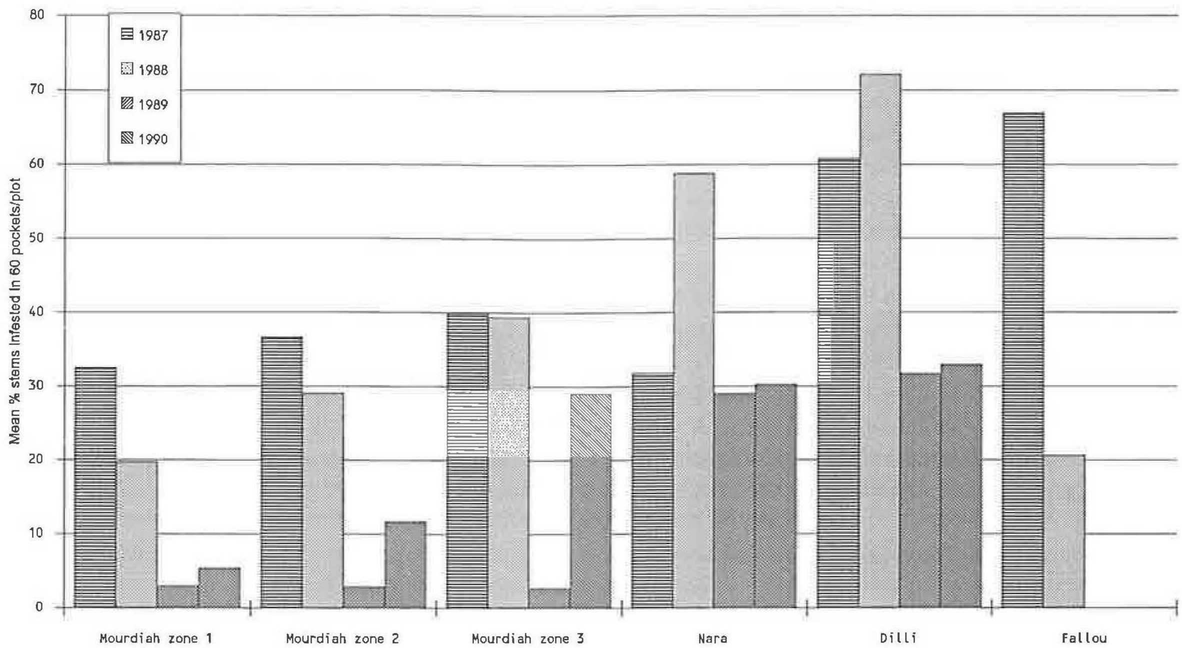

Figure 3 *Coniesta ignefusalis* in north-west Mali on rainfed millet in untreated plots

Pests that appear once every five or six years include the meloid beetles, which in 1989 and 1990 destroyed thousands of hectares of millet. This illustrates the need for flexibility: if a pest appears only once every five or six years, control programmes cannot be prophylactic, but must take into account their incidence. *Pachnoda* flower beetles have also been major pests just one year in six. This supports the idea of a 'menu' chosen by farmers in consultation with entomologists, economists etc., so that a joint decision is reached over the developing situation in any particular year.

It is critical that farmers carry out weeding. It is noticeable that the weeds have not remained stable over the six years of the project - *Striga* has become much more important as a weed pest, and has caused increasing losses.

TOWARDS IPM

Chemical intervention is going to continue but at very low levels. To minimize toxic effects on the people applying the pesticides, they must have good protective clothing and the methods of application must be appropriate. We might try other methods of controlling some of the pests, such as baits, which are easily mixed locally and applied by hand from a tin; dusting, much more effectively applied using a dusting bag than by buying a duster from China or the United States; and ultra-low-volume (ULV) spraying equipment, which can be modified for use by peasant farmers. For example, we have modified such a sprayer using a backpack, which does not require the farmer to keep opening and closing the bottle and fiddling with the nozzle on the application equipment.

The farmers in our region are not self-sufficient in food production, but self-sufficiency is related to family size. The larger the family, the more likely they are to reach self-sufficiency in a year of good rainfall. With the return of good rainy conditions in 1988, 70% of the families in our project area had 12 months' supply of millet for the first time in six years, but small families can never attain this. Our project has never set out to aim for food self-sufficiency, it has always aimed at closing the gap to self-sufficiency, so that it releases some of the resources of the family to use for other requirements. In bad years the large family obtains about four months' supply of millet, whereas the small family always lags behind at about two months' supply.

An understanding that large families patronize the small ones and help them to survive is necessary to enable future IPM programmes at the village level to concentrate on what is best for the community. It is no use coming to this situation with impractical egalitarian ideas. We have also learned not to be naive about the application of pesticides. Farmers follow their own programme: sowing, ploughing, weeding, harvesting, threshing and winnowing, all these activities have to continue. For example, if dusts or granule pesticides are recommended early in the season, between June and August, there is competition for labour with other activities such as planting and ploughing. So at that time of year farmers will resist using pesticides, because in the Sahel farmers aim for an increased area under cultivation as an insurance against rains failure and other problems. But if farmers are asked to apply ULV pesticides in September, when there is a lull between weeding and harvest, we are not competing with other routine activities. It is very important in IPM to avoid imposing new programmes on farmers which would cut back on their ability to survive using their standard procedures.

Farming systems in north-west Mali are complex. Farmers may plant the margins of fields with sorghum to help resist the entry of grasshoppers, a practice which needs no extra labour. Later in the season, the pattern of attack by grasshoppers will differ between bush fields and village fields: because the village fields are planted earlier in the year, there is a much greater tendency to lose field area through early season grasshopper attack. Later on in the year these outlying fields of Sanyo, the long-cycle millet, are badly attacked from the periphery inwards. So again any IPM programme has to take into account the different

Table 1 Crop-loss assessment: itemized percentage losses due to principal pests of millet, north-west Mali, Mourdiah 1990 (millet candles taken from samples of 60 pockets from untreated sample plots)

	Damage category[a]	Plot A	Plot B
Candles in 60 pockets		162	239
Estimated weight[b] (g)		6145	9066
Grains damaged		Candles lost in sample	
(a) Acridids	1	5.88	4.25
	2	2.63	3.0
	3	2.5	3.38
	4	4.38	4.38
(b) Meloid beetles	1	6.3	12.0
	2	6.0	6.4
	3	11.3	24.4
	4	22.8	79.6
(c) Birds	1	0.9	4.3
	2	0	3.0
	3	0	3.4
	4	0	4.0
Total candles lost a+b+c		62.5	152.8
Grains damaged			
(d) *Heliocheilus*[c]			
Grain loss (g)		165	0
Percentage potential grain weight		2.7	0
(e) *Coniesta*			
Percentage loss due to			
- lower candle weight		9.79	5.97
- dead heart		4.32	3.59
TOTAL PERCENTAGE LOSS		55.31	73.49

[a]Damage category figures calculated on the number of damaged candles with up to 25%, 25-50%, 50-75% and 75-100% damage.
To determine number of damaged candle equivalents, the percentage mid-point, i.e. 12.5, 37.5, 62.5, 87.5 was taken.
Example: in plot A there are 5.88 candle equivalents lost in the category with up to 25% grain loss.
[b]Assuming all candles undamaged
[c]*Heliocheilus* damage based on 5 g grain loss per mine.

seasonal pattern of pest attack. Some millet appears to be resistant to attack by the millet head miner caterpillar, but technical investigation shows us that this a pseudo-resistance - in the Sanyo millet the heads which are not attacked actually develop at the emergence stage, well outside the flying time of the moths, thus it is not a true resistance but is due to the developmental cycle of the millet. This knowledge could beapplied within an IPM programme.

Figure 3 demonstrates that the development of these pests needs to be studied over a long period: we cannot afford programmes that last for just two or three years. A period of five to six years is necessary in order to see the full cycle. For example, the figure shows a steady increase in the number of stem borers in the plots, and cycles of this kind can only be detected if research is carried out over a long period.

Crop-loss assessment is necessary to justify the activities of both farmers and plant protection services. Table 1 shows an example of a crop-loss assessment carried out on millet candles, which uses about 150 millet candles per 0.5-ha plot, and enables a very useful estimate of the relative losses of candles. However, if time is limited and a broad survey required, this is not a practical method and we may need to devise socio-economically based crop-loss assessment methods, both for farmers and for plant protection services.

A major problem is the fluctuating price of millet. With a large harvest and consequent glut of millet the price is reduced to almost nothing, which poses problems when IPM involves grain banks. We have used a mean figure of F.CFA 75/kg for the price of millet and, although this is very artificial, it offers a practicalsolution in terms of working out the effectiveness of our interventions. For example, when we treated against millet head miner with ULV pesticide, only 25% of our farmers were getting better than a 2:1 cost:benefit ratio in return, and only half the farmers got better than a 1:1 return for the cost of all inputs into this treatment. This calls into question the whole approach of recommending ULV pesticides to resource-poor farmers.

However, we discovered that pesticides are more cost-effective in the lower-rainfall than in the high-rainfall areas. Also, in 1988 (a high-rainfall year) the mean weight of millet candles produced practically doubled, as the damage to the grain was compensated for by good to near-normal rainfall in August. So we can inform farmers that treatment is less necessary in a good rainfall year because the damage caused by the millet head miner is compensated for by the plants.

A 'MENU' FOR IPM

Our IPM study came up with a 14-point menu.

(i) In order to protect the plants more effectively against the insects which attack the millet candles, we want to start selecting varieties, for example, for long- or short-cycle millet varieties which have a shorter flowering period. There are some advantages to using ULV sprays, but only a tiny proportion of the vulnerable millet candles is actually treated, and once the pesticide has become ineffective a host of new millet candles are produced.

(ii) *Kraussaria* spp. egg pods can be physically destroyed. This is a species which concentrates its egg pods in masses under bushes and small trees, and therefore it is practical to dig them up by the kilogram. This is not expensive and can be done during the dry season. This may also have an impact on meloids like *Psalydolytta*.

(iii) Seed dressings can be applied to reduce insect pests and fungal pathogens. These are already popular with the farmers as the cost per hectare is very low.

(iv) Dry sowing and early sowing are recommended (but advice which technicians have given even recently on planting late to avoid attack is not practical and farmers will not do it).

(v) Intercropping with sorghum, particularly putting a margin of sorghum and a bare perimeter around the field can be very effective, particularly against early season attack from grasshoppers.

(vi) Pesticide dust treatments are comparatively safe and easy to apply but should be limited to a maximum of two treatments.

(vii) With limited resources, protection should be concentrated on the better-producing fields in the villages. This involves an understanding of the sociology of the village - high yielding fields are generally in the charge of the bigger, better-producing families who traditionally will give support to the smaller, poorer-producing families.

(viii) Double weeding should be encouraged.

(ix) ULV should be applied at 50% male flowering stage of the millet crop. It should not be applied if: *Heliocheilus* is less than 25% of the previous year, other pests being generally below danger levels; if *Pachnoda* and *Psalydolytta* thresholds per candle are not reached; if grasshoppers are not present at economic levels on a particular candle stage or grasshoppers have not eaten more than 50% of foliage; or if accumulated August rainfall surpasses or equals that already registered for July.

(x) Instructions should be made available on when not to treat, rather than when to treat, which will save input costs on pesticides.

(xi) End-of-season grasshopper control should be limited to the use of residual dust or a single ULV treatment, under a very small budget.

(xii) Farmers should lay stems flat on the ground before harvest to kill stem borers in the heat of the sun.

(xiii) Pesticide dust or a layer of neem leaves can be applied under the drying millet candles in order to decrease the post-harvest losses immediately prior to threshing.

(xiv) It is most important that the plant protection services monitor the pests continuously to understand the pattern of pest development throughout the year. This will enable them to give sound advice to farmers as pests and rainfall systems develop over the year, and also to make comparisons from year to year. For example a large outbreak of grasshoppers one year can be predicted from the pattern of grasshopper laying at the end of the last season.

SUMMARY

* IPM menus must be extremely flexible to respond to the patterns of seasonal development using regular ground-truth observations. This is not always done by plant protection services.

* IPM at farmer level must increasingly be aimed at crop protection, not at the illusion of global pest control.

* We must identify practical crop-loss assessment methods to allow us to plan and justify inputs, including chemical ones.

* The basis for IPM must be set against a background of socio-economic analysis, and plant protection services should have agro- and socio-economists on their staff, not just in the research units.

* Low levels of chemical control will be necessary but farmers must contribute to this economically and select it in relation to their other priorities - pesticides should not be given as a gift.

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DISCUSSION

S. Mboob (*FAO Regional Office for Africa, Accra, Ghana*). My belief is that for IPM to be successful in the Sahel, we must go in for 'baskets' which are more or less sustainable - if you know the history of the Sahel, there has been heavy dependence on pesticides provided by governments, because of the history of grasshopper and locust plagues. We now have to divert the attention of farmers from dependency to IPM. From your investigation, would you say that Malian farmers would use pesticides, as recommended in this 'basket', if they had to pay for them?

The 'basket' puts too much emphasis on pesticides - you make no mention of natural enemies. What is their role in this system?

N. D. Jago. Unfortunately the role of natural enemies is minimal with most of the pests involved. Many of these pests have far greater control imposed on them by climatic conditions over a period - this applies particularly to grasshoppers, their population levels and migration are controlled principally by the pattern of climatic development, not by the predators that feed on them. Due to their migratory habit, they escape their predators.

I do not believe that farmers would adopt pesticides if they have to pay for them. My hope for the future is that we can at least demonstrate to farmers in a number of pilot villages that if they form village brigades, they can not only reduce the amount of pesticides used in the village, but also make crop protection an economic proposition for the village as a whole. Such a system has been very successful in Burkina Faso. This is where the socio-economic analysis is necessary. It is not the intention to impose a menu on the farmers - we need to sit down in the villages and discuss at length which parts of the menu they feel they would be prepared to adopt. Most of the brigade efforts that are carried out in IPM are political, and no-one has followed up over a series of years to find out whether they are really effective. If they can be shown to be effective and farmers see, over a period of five or six years, that working as a community and purchasing very small quantities of pesticide as a co-operative will work to protect the crops, then farmers will be persuaded. If they are revealed not to be effective, then we need to analyse the reasons for failure.

G. Kibata (*NAL, Nairobi, Kenya*). Is ground monitoring useful for farmers in this context? How much can a farmer gain from the kind of data produced by a ground monitoring team?

N. D. Jago. I would not expect individual farmers to run small light traps or small pheromone traps, for example. This should be the responsibility of the plant protection service. It is absolutely essential, for example, that farmers know when the millet head miner moths are starting to lay eggs, and it is unreasonable to expect farmers to monitor that. If, over a series of years, the millet head miner population has reduced to such levels that the following year it is not going to pick up, the plant protection service can advise all the farmers in an area that there will be no problem next year with *Heliocheilus*, and they can concentrate their efforts on some other pest. Farmers can monitor where grasshoppers have laid much better themselves than any crop protection service, because they can actually watch the grasshoppers laying while they are working in the fields.

Insect pest management in cotton on small-scale farmers' fields in Malawi

G. K. C. NYIRENDA*

Department of Agricultural Research, Ministry of Agriculture, PO Box 30134, Capital Hill, Lilongwe 3, Malawi

ABSTRACT

Cotton plays a major role in Malawi's economy. The crop is grown almost entirely by small-scale farmers with an average landholding of 0.4-1.5 ha. Major insect pests are the bollworms *Diparopsis castanea* and *Helicoverpa armigera*, whereas *Empoasca* spp., *Dysdercus* spp., *Aphis gossypii* and *Tetranychus* spp. are important sucking pests. *Paurocephala gossypii* is a problem locally. Important leaf eaters and stem cutters are *Cosmophila flava*, *Xanthodes graelsii*, *Zonocerus elegans* and termites. The insecticide package for control contains carbaryl, a synthetic pyrethroid, dimethoate, and measuring cups. Synthetic pyrethroids are primarily recommended for *Helicoverpa*, *Taylorilygus* and *Helopeltis* 10-16 weeks after germination. The maximum number of pyrethroid applications is restricted to four sprays in any one growing season. Carbaryl is recommended for the control of *Diparopsis* and leaf-eating insects, whereas dimethoate is recommended for *Aphis* and *Tetranychus*. In addition, thiodicarb is recommended for *Diparopsis* and leaf eaters, and endosulfan for *Helicoverpa*. The insecticides are applied mostly in relation to action levels for major bollworms, aphids, psyllids and red spider mites. Scouting for insect pests on farmers' fields is done by extension workers and by a limited number of farmers, either in clubs or individually. Farmers are trained at farmer training centres and credit clubs. A peg board is used to record scouting results by some illiterate farmers, but these are few. Scouting results by extension staff are communicated to farmers in various ways, including placing of the results at an agreed place in a chief's village, and farmers are individually requested to seek advice from the extension staff in their area and listen to the radio. Pesticides are applied with knapsack, spinning-disc and tailboom sprayers.

RESUME

Le coton joue un rôle majeur dans l'économie du Malawi. Il est cultivé presque entièrement par des petits exploitants qui possèdent des parcelles de 0,4 à 1,5 ha en moyenne. Les principaux insectes nuisibles sont les chenilles *Diparopsis castanea* et *Helicoverpa armigera* tandis que *Empoasca* spp., *Dysdercus* spp., *Aphis gossypii* et *Tetranychus* spp. sont des fléaux importants. *Paurocephala gossypii* pose un problème localement. *Cosmophila flava*, *Xanthodes graelsii*, *Zonocerus elegans* et les termites sont des fléaux importants qui dévorent les feuilles et coupent les tiges. Le "paquet" d'insecticides utilisé pour la lutte contre les ravageurs contient du carbaryl, une pyréthroide synthétique, du diméthoate et des gobelets gradués.Des pyrethroides synthétiques sont surtout recommandées pour *Helicoverpa*, *Taylorilygus* et *Helopeltis* 10 à 16 semaines après la germination. Le nombre maximum d'applications de pyréthroide est limité à quatre pulvérisations par campagne. Le carbaryl est recommandé contre *Diparopsis* et les insectes dévorant les feuilles, tandis que le diméthoate est recommandé contre *Aphis* et *Tetranychus*. En outre, le thiodicarb est recommandé contre *Diparopsis* et les dévoreurs de feuilles et l'endosulfan contre *Helicoverpa*. Les insecticides sont principalement appliqués selon les niveaux de seuil des chenilles, pucerons, psylles et acariens rouges principaux. Déceler les insectes nuisibles dans les champs des paysans est la tâche des agents de vulgarisation et d'un nombre limité de paysans soit individuellement, soit regroupés en coopératives de crédit. Les paysans sont formés dans des centres de formation et des coopératives de crédit. Certains paysans illettrés utilisent un panneau pour enregistrer les résultats du dépistage mais leur nombre est peu élevé. Les résultats du dépistage effectué par les agents de vulgarisation sont communiqués aux paysans de diverses manières, y compris le placardage des résultats à un endroit convenu dans le village du chef, et l'on conseille aux paysans de demander l'avis des agents de vulgarisation dans leur région et d'écouter la radio. Les pesticides sont appliqués à l'aide de pulvérisateurs à dos, à disque rotatif et à rampes.

INTRODUCTION

Cotton plays an important role in the economy of Malawi which is primarily agricultural. About 75% of the cotton lint produced annually is consumed by the local textile manufacturing industries. Locally manufactured textiles have replaced a large quantity of imported textiles; some are exported overseas. Exported finished textiles and raw lint earn valuable foreign exchange for the country. Cotton seed is crushed for cake for livestock feed and cooking oil. The crop helps farmers to earn a reasonable and reliable income

*Paper presented by Mr J. W. Mchowa, Makoka Research Station, Private Bag 3, Thondwe, Malawi.

from the sale of seed cotton. The textile industries provide employment to over 3000 urban dwellers.

COTTON PRODUCTION

Cotton production has risen from two bales (180 kg per bale) in 1902 to the current level of between 40 000 and 56 000 bales. The crop is grown almost entirely by 30 000-80 000 small-scale farmers on 45 000-60 000 ha annually. The average field size is 0.4-1.5 ha. The crop is grown in low-altitude areas of the lakeshore and Shire Valley and in mid-altitude areas of the Shire Highlands, the Nkhamanga plains and the Henga Valley. Cotton production is constrained by a number of limiting factors - insect pests are one of the major limitations.

INSECT PEST COMPLEX

In Malawi, cotton is attacked by several insect pests; the most important ones may broadly be grouped as bollworms, leaf- and stem-eating insects, and sucking insects.

Bollworms

As a group these are major pests throughout the country each year. There are four important bollworms in Malawi:

(i) *Diparopsis castanea* (red bollworm) is a major pest in all cotton-growing areas of Malawi. Damage to cotton is usually from the first flower-bud stage (six weeks after germination) until when the crop matures. The insect damages flower buds and young and maturing bolls. Under special conditions it damages growing tips, resulting in tip boring. Loss in yield has been estimated at various levels by various authors, but ranges between 10 and 48% (Marks, 1978).

(ii) *Helicoverpa armigera* (African bollworm) is a major pest of cotton throughout Malawi. Damage is restricted to flower buds, flowers, young and maturing bolls, but in most seasons the main wave of attack is during the peak flowering of cotton. Severe infestations occur from time to time which result in considerable damage and loss of yield. In some individual fields, plants may be stripped of all bolls (G.K.C.N., unpublished data, 1982; 1987). Losses are variable but may be up to 70% in some seasons in individual fields and localized areas.

(iii) *Pectinophora gossypiella* (pink bollworm) is considered a serious pest but its exact status is not well established. However its presence has resulted in the cessation of cotton growing in some areas and the introduction of the current closed season recommendations (Nyirenda, 1986). Damage to cotton bolls may be as high as 60% in some years in some fields, in areas where the pest is endemic. Nationally, losses may be less than 20% of yield.

(iv) *Earias insulana* and *E. biplaga* (spiny bollworms) occur throughout the country but serious damage in the form of tip boring occurs in localized areas in some seasons. No loss figures are available, but losses may be less than 5%.

Sucking pests

There are many sucking pests in Malawi but not all are important.

(i) *Aphis gossypii* (the cotton aphid) occurs throughout Malawi, and damage is most serious during the dry weather conditions at the beginning and towards the end of the season. Yield loss figures are not available but lint quality may be seriously affected. Heavy infestations early in the season may result in stunting.

(ii) *Empoasca fascialis* (the cotton jassid) is most damaging at the beginning of the season. Yield losses may be over 50% in susceptible varieties, and up to 15% with some tolerant or resistant varieties. In Malawi the pest has largely been controlled by growing resistant varieties.

(iii) *Dysdercus* spp. (cotton stainer): the most important species in Malawi are *D. fasciatus* and *D. intermedius*. Yield losses may be as high as 40% in some seasons, especially when overcast weather conditions prevail during the boll maturing period. In some seasons stained lint may be as high as 70%, which results in downgrading of the lint.

(iv) *Tetranychus* spp. (red spider mites) are especially important during the early part of the season. However, the pest generally appears at high infestation levels during the later half of the season when dry weather conditions favour its build-up. There are no yield loss data available.

(v) *Paurocephala gossypii* (cotton psyllid) occurs throughout the country but is less abundant in areas below 300 m above sea level. The insect causes the disease psyllose in cotton, but in Malawi psyllose is only expressed in localized and specific areas (McKinley, 1965; G.K.C.N., unpublished data, 1990). Losses may be total, and the disease is irreversible once symptoms have started to appear.

Cutting and leaf-eating insects

There are several leaf-eating insects but only a few are important.

(i) *Cosmophila flava* and *Xanthodes graelsii* are the most important loopers in Malawi. Damage is most noticeable during the early half of the season but no yield loss figures are available.

(ii) *Zonocerus elegans* (elegant grasshopper) is most serious at the beginning of the season when it attacks seedlings. In some seasons seedlings are totally destroyed, and in some areas farmers may plant three times.

(iii) Termitidae (white ants) and *Hodotermes* (harvester termites): several termites attack cotton, especially seedlings. As with elegant grasshoppers, farmers may replant the whole field. However after the crop has been established it is felt that yield loss as a result of termite damage is minimal - the crop can stand up to 40% loss in plant populations.

INSECT PEST MANAGEMENT

The current insect pest management strategy is to encourage an integrated approach, although this involves a number of difficulties as cotton is grown almost entirely by small-scale farmers. The literacy level of most of the farmers is low.

Biological control

Although natural enemies of some cotton insect pests had been identified earlier this century, field studies established that the natural enemies were largely ineffective (Parsons & Ullyett, 1934). Apart from the work of Pearson (1958) no efforts have been made to identify the range of natural enemies and their efficiency in the control of cotton insect pests in Malawi.

However, in conjunction with institutes of the UK Overseas Development Administration (forerunners of the Natural Resources Institute), sex pheromones for red bollworm, African and pink bollworms have been identified and tested in Malawi with the possibility of using the sex pheromones for monitoring and bollworm control. In the past, work has been hampered by the lack of appropriate formulations. Now, with the availability of pink bollworm sex pheromone formulations suitable for field application, there is an opportunity to assess the efficacy of red and pink bollworm sex pheromones on small-scale farmers' fields in Malawi; however financial resources are lacking.

With suitable weather patterns, parasites (*Aphidius* spp.) and predators (lacewings, coccinellids and syrphid flies) may exert reasonable control of relatively high aphid infestations. In humid weather, an unidentified fungus believed to be *Empusa frensii* has been observed to give good control (Matthews, 1971). As a result of the effective control of aphids by natural enemies, the threshold level for spraying against aphids is relatively high at 25-33% of the total plants scouted scoring medium levels (11-30 aphids of all stages per leaf) depending on the weather pattern.

Cultural control

The recommended closed season for cotton growing in Malawi is aimed primarily at preventing red and pink bollworms and the cotton psyllid from carrying over from one season to the next. When uprooting of cotton stocks is neglected in areas where pink bollworm and psyllids are endemic, there are outbreaks of pink bollworm and psyllose (Matthews *et al.*, 1965; Nyirenda, 1986). The closed-season recommendation is to plant cotton after the first effective planting rains at 50 mm, or alternatively to wet of the soil to a depth of at least 150 mm from mid-November. All cotton plants must be burned by 15 August except in Karonga, where the plants must be burned by the end of September. Cotton jassid is largely controlled by strictly growing varieties that have been bred for resistance or tolerance to jassid.

Chemical control

The wide range of cotton insect pests, and the ineffective control by natural enemies, convinced entomologists of what was then the Central African Cotton Pest Research Scheme based at Gatooma, Rhodesia that insecticides were the only viable method for controlling cotton insect pests, at least for the time being (Tunstall *et al.*, 1959).

Insecticide recommendations

The insecticide package currently made available to small-scale farmers in Malawi has been modified from the early insecticide package which was recommended in the early and mid-1960s (Tunstall & Matthews, 1963; 1966).

(i) Carbaryl, a carbamate insecticide, is recommended to control *Diparopsis castanea*, *Earias* spp., *Empoasca* spp., *Paurocephala gossypii* and various leaf eaters namely *Cosmophila*, *Xanthodes*, *Spodoptera littoralis*, *Plusia* spp. and elegant grasshoppers. Carbaryl has been used on cotton since the early 1960s.

(ii) Thiocarb, a carbamate insecticide, is recommended for the same pests as carbaryl and also to control *Helicoverpa armigera*. Recent studies suggest that it is more effective against *Pectinophora gossypiella*. However, like carbaryl it encourages the build-up of red spider mite if applied over a long period.

(iii) Endosulfan, an organochlorine insecticide, is recommended for the control of *Helicoverpa* mainly for aerial application and where possible on commercial farms. Application of endosulfan is not encouraged by small-scale farmers as it is relatively more toxic than other recommended insecticides. However, it is less damaging to natural enemies than other insecticides and does not lead to red spider mite build-up.

(iv) Synthetic pyrethroids have replaced DDT in the original spray programme. Pyrethroids currently

Table 1 A comparison of spray concentrations, dilution rates and amounts of product per load for two methods of application

Insecticide	Carbaryl	Cypermethrin		Deltamethrin	Fenvalerate	Cyfluthrin	Lambda-cyhalothrin	Thiodicarb	Dimethoate	
Knapsack with tailboom sprayer										
Formulation	WP	EC	WP	EC	EC	EC	EC	FW	EC	WP
Percentage a.i. concentration	85	20/25	20	2.5	20	5	5	37.5	40	20
Percentage a.i. spray	0.5	0.0147		0.0029	0.01875	0.0045	0.0045	0.20	0.05	0.05
Amount product/14 l water	85g	10/8ml	10g	15ml	13ml	12ml	12ml	72ml	17ml	34g
Spinning disc sprayer										
Formulation	WP	EC	WP	EC	EC	EC	EC	FW	EC	WP
Percentage a.i. concentration	85	20/25	20	2.5	20	5	5	37.5	40	20
Percentage a.i. spray	6.8	0.20		0.039	0.255	0.0612	0.0612	2.72	0.68	0.68
Amount product/1 l water	85g	10/8ml	10g	15ml	13ml	12ml	12ml	72ml	17ml	34g

recommended are cypermethrin, deltamethrin, fenvalerate, cyfluthrin and lambdacyhalothrin (Anon., 1989). Although the pyrethroids are effective against a wide range of insects including *Diparopsis*, they are only applied during the main flowering period, mostly against *Helicoverpa* and *Pectinophora*. Pyrethroids will also control *Taylorilygus* spp. and *Helopeltis* spp. Some pyrethroids such as fenvalerate, cyfluthrin and lambdacyhalothrin do not appear to induce a rapid build-up of red spider mite. Aphid infestations are controlled by pyrethroids.

(v) Dimethoate, an organophosphate insecticide, is applied to control *Aphis* spp., *Tetranychus* spp. and *Paurocephala.*

Application of pesticides has resulted in an average increase of seed cotton yields from 150-300 kg/ha unsprayed, to 700-1000 kg/ha sprayed, and up to 2500 kg/ha in some cases. Well-sprayed cotton results in up to 90% grade A seed cotton and high-grade seed for sowing.

Application techniques

The recommended insecticides are applied with a knapsack sprayer mounted with a tailboom to achieve adequate coverage of foliage at all stages (Tunstall *et al.*, 1965) and hand-carried spinning disc sprayers (Matthews, 1971; Mowlam *et al.*, 1975). The volume applied ranges from 56-200 and 3-12 l/ha with the knapsack mounted with tailboom and the spinning disc sprayers, respectively, depending on the height or size of the cotton crop (Nyirenda, 1986). The concentrations at which the insecticides are applied are presented in Table 1.

Table 2 Action levels for some cotton insect pests

Diparopsis	any presence of eggs 6 weeks after germination except when *Helicoverpa* is being controlled
Helicoverpa	0.25 per plant
Aphis	25-33% for all plants scouted on 168 leaves
Tetranychus	when spotted in the early or mid season on 100 leaves scouted
Taylorilygus	25% for all plants scouted
Helopeltis	25% for all plants scouted
Bemisia	5-10 adults per leaf on 168 leaves scouted, but needs to be confirmed
Dysdercus	Unavailable
Zonocerus	Unavailable

Scouting

It is recommended that insecticides are applied after the cotton fields have been scouted to decide which insect pest is present and whether spraying is justified. The economic thresholds or action levels for some pests are presented in Table 2. These action levels are based on 24 plants scouted except for *Tetranychus*, *Empoasca* and *Aphis*. However, there is no definite threshold for *Diparopsis* but spraying is recommended if eggs are seen from six weeks after germination, usually when first flower buds begin.

Early sprays of carbaryl are recommended to control *Zonocerus*, *Empoasca*, some lepidopterous leaf-eating insects, and *Paurocephala* as necessary. Dimethoate is applied to control aphids if the weather is hot and dry or against *Tetranychus* and *Paurocephala*.

The current recommendation to apply insecticides after scouting is sound, as insecticides are applied only when necessary. It ensures the delay of resistance and pest resurgence. So far field resistance has not been reported, although this may be because resistance has not been monitored. Lack of resistance may also be due to the fact that in the main cotton-growing area, only about 45% of farmers spray their cotton. The whitefly problem that has afflicted some cotton-growing countries is not yet serious, although populations are relatively higher in some areas than they were about ten years ago. This could be because pyrethroids are restricted to a specified period and have only been used on a wide scale since 1986.

Although scouting has been recommended for several years now there are a number of problems associated with it.

Illiterate farmers

Illiterate farmers cannot record results and some old farmers are unable to detect small insects. In addition, failure to identify insect pests can be a serious problem. As an attempt to alleviate the illiteracy problem a peg board was introduced (Figure 1; Beeden, 1972). Although a few farmers are still using the peg board, its impact has been limited by a lack of constant farmer training in its use due to limited financial resources. Originally up to 8000 farmers were using the peg board in the Shire Valley and some upland areas (F. Anthuacino, personal communication, 1981) but this number is now believed to be under 2500.

Use of extension staff

The effectiveness of the scouting system has largely depended on extension staff who divide their areas into three to five scouting zones. In each zone, up to five fields are scouted depending on the size of the zone. The problem with this approach lies in the fact that pest attack in all fields is not necessarily represented by the scouted fields and some farmers may be spraying inappropriately. Because of the large number of farmers and long distances between farmers, farms scouted represent a very small proportion. Ideally farmers should scout their own fields. The introduction of the peg board was partly in answer to this problem.

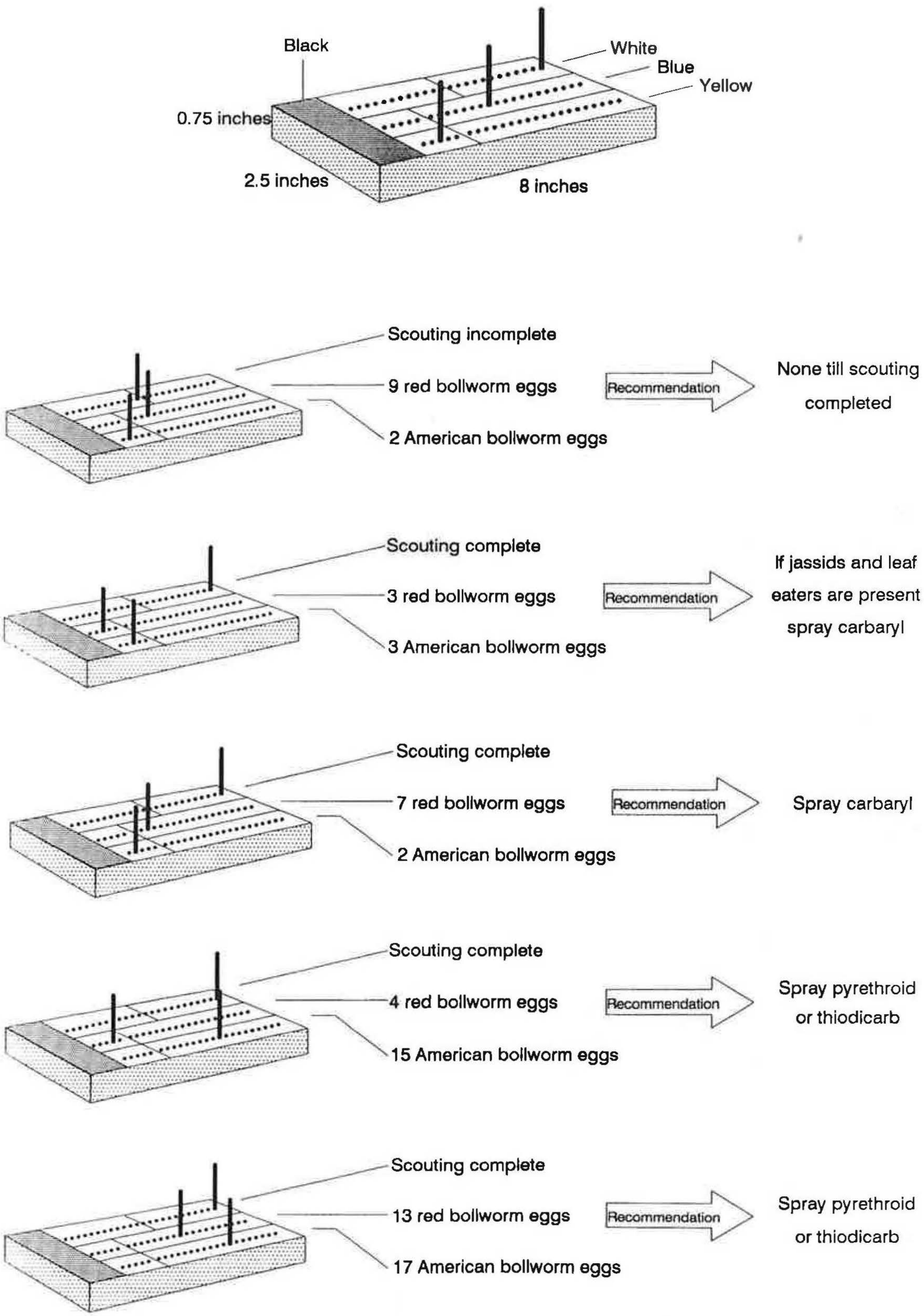

Figure 1 Peg board used by some farmers to record scouting results in decision-making for spraying

Further attempts to solve this problem have been to train farmers belonging to credit clubs. These clubs usually have a common cotton field among other crop fields. Farmers use the results obtained in their club's field; they are also requested to scout their own fields and confirm the results obtained in the club's field. A club may have up to 30 members.

Communication of extension results

Communication to farmers of scouting results obtained by extension workers is a serious problem. This is particularly so for the many farmers who do not belong to clubs. However, many attempts have been made to overcome this. In some areas results of the week are pinned on an agreed marker in a chief's village. Clubs are also used to communicate results to both club and non-club farmers. Radio broadcasts encourage farmers to consult with extension workers in their areas.

Changing of insecticide regimes

In the earlier recommendations, the change from carbaryl to DDT or *vice versa* created special problems, particularly as such a change was sometimes critical in order to avoid serious damage. This was particularly so with *Helicoverpa*, as infestations can appear suddenly. However, the introduction of pyrethroids and thiodicarb has reduced this problem, as farmers are requested to apply pyrethroids only during the period from 10-12 to 14-16 weeks after germination. Thus in the Southern Region pyrethroids are recommended for application from 21 February to 21 March, and from 1 to 31 March in the Central and Northern Regions, to coincide with the peak flowering period of cotton. The recommended four pyrethroid applications in a season are a maximum per season but applications could be less if the insect pressure is less than the threshold levels. Investigations are under way to establish how much a farmer loses if rains start too late or too early, such that the peak flowering period is not synchronized with the pyrethroid application period.

Insecticide packages

The recommended insecticides are produced in a special cotton pack (Figure 2) containing sufficient insecticides to cover 0.4 ha or 1 ha, as presented in Table 3. The Agricultural Marketing and Development Corporation (ADMARC), a statutory body of the government, is requested to pack and sell these insecticides. Similarly, credit to farmers for cotton insecticides is issued on the basis of the cotton pack. The amount of carbaryl is being increased to ensure adequate supplies for 4-6 sprays per growing season. The full package

Figure 2 Cotton packs produced by the Agricultural Marketing and Development Corporation of Malawi

Table 3 Examples of some farmers' cotton insecticide pack

Insecticide	Units	Amount in package per season Area in ha 0.4	1.0
A			
Carbaryl (85s sachets)	g	26 x 85	65 x 85
Dimethoate (20 WP sachets)	g	10 x 34	25 x 34
Cypermethrin (20 EC)	ml	250	760
B			
Carbaryl (85s sachets)	g	26 x 85	65 x 85
Dimethoate (20 WP sachets)	g	7 x 34	24 x 34
Lambdacyhalothrin (5 EC)	ml	250	912

contains carbaryl, a synthetic pyrethroid and measuring cup, and dimethoate. On estates this may include thiodicarb and endosulfan. Some agrochemical companies involved in the sale of pyrethroids have not co-operated fully in restricting pyrethroids to a few applications and to a specific period.

LESSONS LEARNED

* Although farmers are aware of the benefits of applying pesticides only when necessary, and many carry out some form of scouting or crop inspection, many still use pesticides inappropriately.

* Use of packages involving scouting and specific application of pesticides requires sustainable training inputs with regard to both farmers and extension workers. Such training should be continuous. For maximum effects there is a need for specialized extension staff in pest management.

* Some farmers are willing to take on scouting of their own fields, but the numbers are unknown and believed to be small. However, others feel that it is the job of extension officers to scout the farmers' fields. The officers are paid for this.

* With the introduction of pyrethroids, many farmers did not like to use other pesticides. This attitude was also encouraged by some of the chemical companies marketing pyrethroids, but gradually farmers have accepted the idea of restricting pyrethroids and companies have been told to follow government recommendations.

* Pest control strategies in small-scale farming systems involving the use of pesticides must be based on appropriate, simple application techniques. Sprayers and other equipment must be durable and lightweight. Many farmers complain about a lack of spare parts for spraying equipment, etc. After-sales service needs to be improved.

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DISCUSSION

P. Jowah (*Cotton Research Institute, Kadoma, Zimbabwe*). It is well known that some of the pyrethroids you have recommended in Malawi are a cause of spider mite outbreaks. IPM places the emphasis on minimum use of insecticides. What are you doing about the other chemicals, including cypermethrin and deltamethrin which cause outbreaks, which means more insecticide is necessary to control spider mite?

J. W. Mchowa. Of those insecticides we recommend for the control of the African bollworm, there are agents selling cypermethrin, deltamethrin, lambdacyhalothrin and thiodicarb. We would prefer lambdacyhalothrin, cyfluthrin and fenvalerate, but there are no agents for the latter two. Cypermethrin and deltamethrin have been kept for economic reasons, and will be removed from the recommendations later.

E. A. Babiker (*Ministry of Agriculture, Khartoum, Sudan*). We have such an IPM programme for cotton pests in Sudan which is now progressing very well, and productivity is increasingly higher than for sprayed fields. What is the reason for the high level of chemical applications in the package you recommend? We have the same pests in Sudan. This level of insecticides does not allow any chance for the survival of natural enemies. On this basis, would you agree that your IPM programme has been a failure?

J. W. Mchowa. The IPM system in Malawi is not a failure: farmers are able to choose the right chemical at the right time, not spraying when they don't have to spray. Not all of the chemicals in the recommended package are used by farmers. Also, all our varieties are jassid-resistant, which means insecticides are not necessary until six weeks after germination. And as there is no chemical that gives effective control of pink bollworm, a closed season is enforced.

Biological control in cassava: a viable crop protection package for resource-poor farmers

W. N. O. HAMMOND, P. NEUENSCHWANDER, J. S. YANINEK & H. R. HERREN

International Institute of Tropical Agriculture / Biological Control Program, BP 08-0932, Cotonou, Republic of Benin

ABSTRACT

The fragile cassava agro-ecosystem in Africa was weakened by the accidental introduction of the cassava mealybug (CM), *Phenacoccus manihoti* Matile Ferrero, and the cassava green mite (CGM), *Mononychellus tanajoa* Bondar, which cause up to 80 and 60% yield loss, respectively. To restore the balance, the development of ecologically sustainable inputs was initiated by the IITA/BCP in collaboration with several institutions. Classical biological control, using the exotic encyrtid parasitoid *Epidinocarsis lopezi* De Santis, was successfully implemented on the cassava mealybug at no cost to the resource-poor farmer. By 1990, *E. lopezi* had spread over an estimated area of 2.7 million km^2, of which about 1% is under cassava cultivation. Seven years of continuous monitoring in numerous fields in two areas of south-western Nigeria revealed that mean CM population peaks dropped from more than 90 CM/cassava tip to about 10 and never reached the original high level. Extensive surveys in Nigeria, Benin, Gabon, Zaire and Congo confirmed overall low CM infestation levels of below 10 CM/cassava tip. For CGM some promising phytoseiids have recently been obtained, and the first establishment of exotic phytoseiids has now been confirmed in Benin. To achieve ecologically sustainable cassava plant protection, classical biological control with phytoseiids and pathogenic fungi against CGM, complemented by cultural control and host-plant resistance, has been initiated for other cassava pests as well. Farmer participation, training of national research scientists, and the development of national programmes are all important components of this package.

RESUME

L'agro-écosystème fragile du manioc en Afrique a été affaibli par l'introduction accidentelle de la cochenille farineuse, *Phenacoccus manihoti* Matile Ferrero, et de l'acarien vert du manioc, *Mononychellus tanajoa* Bondar, qui causent des pertes de rendement pouvant atteindre 80 et 60% respectivement. Pour rétablir l'équilibre, la mise au point d'intrants durables du point de vue écologique a été initiée par l'IITA/BCP en collaboration avec plusieurs institutions. La lutte biologique classique contre la cochenille farineuse du manioc, utilisant *Epidinocarsis lopezi* De Santis, un parasitoide exotique de la famille des Encyrtides, a été menée à bien avec succès et gratuitement pour les paysans disposant de peu de ressources. En 1990, *E. lopezi* s'est répandu sur une superficie estimée à 2,7 millions de km^2, dont 1% environ consiste en culture de manioc. Sept années de surveillance continue dans de nombreux champs, dans deux régions du sud-ouest du Nigéria, ont révélé que la population moyenne de cochenille farineuse a chuté de plus de 90 cochenilles par apex à environ 10 et n'a jamais retrouvé son niveau élévé d'origine. Des études approfondies au Nigéria, au Bénin, au Gabon, au Zaire et au Congo ont confirmé des niveaux d'infestation faibles en général, avec moins de 10 cochenilles par apex. En ce qui concerne l'acarien vert, quelques phytoséides prometteurs ont été récemment obtenus et le premier établissement de phytoséides exotiques a maintenant été confirmé au Bénin. Pour arriver à une protection du manioc qui soit durable du point de vue écologique, la lutte biologique classique contre l'acarien vert, utilisant des phytoséides et des champignons pathogènes et complétée par la lutte au niveau cultural et la résistance de la plante-hôte, a été initiée également contre les autres ravageurs du manioc. La participation des paysans, la formation des chercheurs nationaux et la mise sur pied de programmes nationaux sont des éléments importants de cet ensemble de mesures de protection des végétaux.

INTRODUCTION

Cassava, *Manihoti esculenta* (Euphorbiaceae), was introduced from South America in the 16th century, and has become a key component in many traditional cropping systems in Africa. It is a crop which contributes significantly to meeting the caloric demand of the rapidly growing urban and rural populations. Easy to grow even under harsh agronomic conditions, cassava is a primary source of carbohydrates, animal feed and food security for more than 200 million of the poorest people in Africa. Cassava also provides raw material for rural agroindustries, an important source of rural income.

Being an exotic plant, cassava had been relatively free of arthropod pests in Africa (Herren & Bennett, 1984) compared to its area of origin. The rapidly increasing demand for cassava production is transforming the delicate balance within the often fragile agroecosystems. In Africa, farmers have reduced fallow periods and now cultivate increasing marginal areas. Pests, defined as arthropods and pathogens, represented a significant production constraint causing estimated production losses of 50%. Since the accidental introduction from South America of the cassava green mite (CGM), *Mononychellus tanajoa* (Acari: Tetranychidae), in 1971, and the cassava mealybug (CM), *Phenacoccus manihoti* (Hom: Pseudococcidae), in 1973, to East and Central Africa, respectively, there has been a sharp increase in yield losses across the cassava belt of Africa.

CM and CGM cause direct losses of up to 80 and 60%, respectively (Nwanze, 1982; Schulthess, 1987; Yaninek & Herren, 1988), depending on the physiological state of plants, which is influenced by environment and other pests and diseases. In addition secondary losses like the reduction of healthy leaves, which are consumed in many countries, erosion, weed invasion, and poor planting material for use in the next planting season also contribute to the problem. At present, with the exception of Uganda and Madagascar, CM occurrence extends from Senegal in the extreme west across 32 countries to Mozambique in the south-eastern corner of the continent, covering more than 90% of the African cassava belt. By 1990 the CGM was homogeneously distributed throughout the cassava belt, with the major exceptions of Senegal, The Gambia and Madagascar.

To restore the balance within the fragile agroecosystems, the development and implementation of ecologically sustainable inputs is especially urgent. Sustainability can only be achieved by considering the management of the system as a whole. In this paper, we present an account of the classical biological control of the CM as a component of a crop protection package for resource-poor farmers in Africa and outline other ecologically sound strategies for the control of other cassava pests, particularly the CGM. The paper highlights scientific evaluations of CM control, and packages for the control of CGM and other pests of importance. We also focus on the importance of farmer participation, and how training and the development of national biological control programmes in Africa are essential for the successful implementation of ecologically sound pest control.

CONTROL STRATEGY

The accidental introduction of these two pests, CM and CGM, threatened the food security of many African countries and caught the attention of governments and the international donor and research communities. Following early and unsuccessful attempts to introduce natural enemies against CM and CGM (Yaseen, 1986), the International Institute for Tropical Agriculture (IITA) started work in biological control and host-plant resistance. This led to the creation of the IITA Biological Control Programme (BCP), which developed a comprehensive research programme and co-ordinated collaboration with scientists in Africa, Europe and the Americas (Herren, 1981; 1987).

In order to control these pests IITA adopted the following strategy:

(i) systematic exploration of the likely areas of origin of the pests which were conducted from southern California to Paraguay

(ii) rearing of most promising natural enemies, and detailed taxonomic, biological and ecological studies

(iii) the release of selected beneficials in Africa over an infested zone that is one and half times the size of the USA

(iv) an analysis of the cropping system and economic impact of the pests and their indigenous and introduced natural enemies.

These activities were conducted by IITA in collaboration with several international organizations and national crop protectionists, at no cost to resource-poor African farmers.

BIOLOGICAL CONTROL OF THE CASSAVA MEALYBUG

Releases

Between 1981 and 1991, several exotic beneficial agents were released against the CM across the cassava belt in over 100 areas, but only a few became established. Among them the encyrtid parasitoid, *Epidinocarsis lopezi*, became established in all the ecological zones where the cassava mealybug occurs. By 1990, *E. lopezi* was established in 25 African countries and had spread across an estimated area of 2.7 million km^2 (Figure 1), of which about 1% is under cassava cultivation, under different ecological conditions (Herren & Neuenschwander, 1991). Among the CM predators, *Diomus* spp. became established only in Kinshasa (Hennessey & Muaka, 1987) and Malawi (Herren & Neuenschwander, 1991) and *Hyperaspis notata* in Burundi (W.N.O.H., unpublished data) and the Kiyu province of Zaire (N.H.D. Nsiama, unpublished data, 1988).

Impact assessment

Following releases and establishment of exotic species, more serious efforts have been invested in impact assessment, an often neglected part of biological control projects, but a very important yardstick of any operation. Physical and chemical exclusion experiments demonstrated the efficiency of *E. lopezi* in reducing CM populations in south-western Nigeria (Neuenschwander *et al.*, 1986) and the rainforest zone in Ghana (Cudjoe *et al.*, in press).

The clearest demonstration of a parasitoid's impact is usually obtained from data on population dynamics. Seven years of continuous monitoring in numerous fields in two areas of south-western Nigeria revealed that mean CM population peaks never reached the height (means of up to 90 CM/tip) observed during the first season of release (Hammond & Neuenschwander, 1990). Though occasional sharp peaks of up to 30 CM per tip were registered, *E. lopezi* maintains a high level of biological control in this area (Figure 2).

In large-scale extensive surveys, it was demonstrated that, within two years of *E. lopezi*'s establishment, the average percentage of stunted cassava plants fell from 88 to 23%, leaving mean population densities at the end of the dry season, i.e. the time of maximum CM infestations, at about 10 per tip (Neuenschwander & Hammond, 1988). This method gives only a snapshot of fluctuating and ever-changing conditions, but the key to the successful extrapolation of the data consists of a rigorous sampling procedure with an unbiased

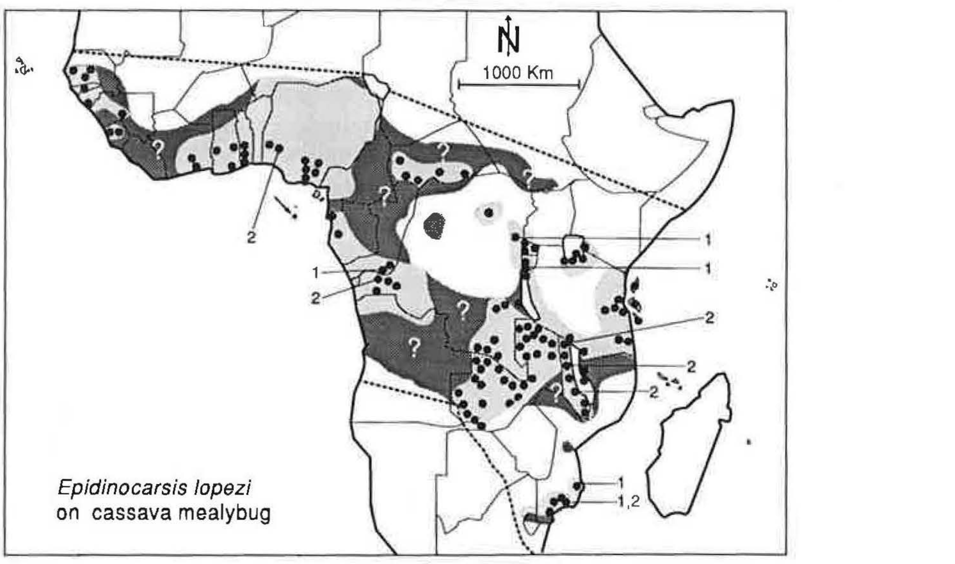

Figure 1 Distribution in Africa of *Phenacoccus manihoti* (dark shading) and its introduced parasitoid *Epidinocarsis lopezi* (light shading) and of two exotic coccinelids, (1) *Hyperaspis* sp. and (2) *Diomus* sp. Dots, release sites with establishment (adapted from Cudjoe *et al.*, 1992).

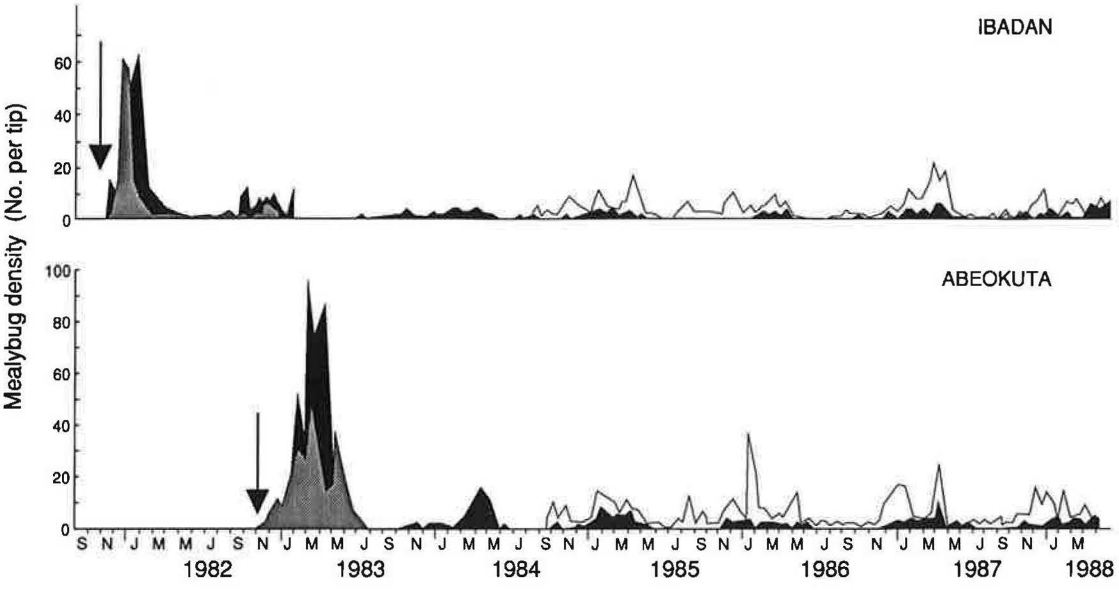

Figure 2 Population dynamics of the cassava mealybug *Phenacoccus manihoti* on IITA-improved (grey and black) and local farmers' (white) cultivars at two locations, Ibadan and Abeokuta, in Nigeria from 1981-88. Arrows, release of *Epidinocarsis lopezi*. Grey, release fields; black, control fields which were soon invaded (adapted from Hammond & Neuenschwander, 1990).

choice of fields and tips to be sampled (Herren & Neuenschwander, 1991). In another follow-up survey covering the whole of Nigeria and Benin four years later, it was confirmed that overall CM infestation levels were below 10 per tip, with only 3.2% of all tips stunted. Infested fields were concentrated on leached-out soils without mulch which comprised 4.8% of all fields (Neuenschwander *et al.*, 1990). Similarly in Gabon, Zaire and Congo, with the exception of *Manihot glassiovi* which usually had more than a thousand CM/tip, the overall mean density was less than 10, with 10.4 of all tips stunted (Hammond *et al.*, 1989).

In addition to the ecological assessment, an economic evaluation of the impact of *E. lopezi* on cassava yields was done by a large-scale survey across different ecological zones in Ghana and Côte d'Ivoire. Econometric multiple regression analysis showed that the loss due to the CM was reduced significantly by an average of 2480 kg/ha in the savanna region where *E. lopezi* had been present for most of the planting season, compared to areas where *E. lopezi* was not yet established (Neuenschwander *et al.*, 1989).

Despite these positive results, professional and lay perceptions of this impact have varied greatly from one country to another. The problems still encountered within the cassava belt include the following.

(i) The CM is still spreading in various countries. Consequently, nationwide damage remains high, even if *E. lopezi* has brought the CM under control in the first release sites.

(ii) Within a large area under the umbrella of biological control by *E. lopezi*, individual fields or corners of fields always have comparatively high infestations. Most of these infestations have been shown to be the result of bad farming practices.

(iii) Biological control activities are free to the farmer and, most often, to the governments as well. They sometimes lead to the funding of a project or are coupled with food aid to the farmers. Therefore socio-economic interests exist in declaring CM infestations a continued disaster.

(iv) Ignorance about mechanisms of pest impact and biological control has sometimes led to false expectations.

(v) Chemical control during grasshopper outbreaks within the cassava ecosystem leads to resurgence of CM. This was the case in the Brong Ahafo region of Ghana in 1989 when, after several reports of

CM outbreaks in this area (from previous surveys the pest had been observed to be under control), the Ghana National Biological Control Program investigated and found that the fields in question had been severely attacked by *Zonocerus variegatus* in the previous season and therefore treated with diazinon and Elocron (K. Kyei-Antwi, K. Korang-Amanquah & R. Adjakloe, Ghana, unpublished data, 1989). Also, in this area, vegetables which are usually intercropped with cassava are sprayed against insect pests and diseases. Obviously natural enemies were eliminated by this action, resulting in a sudden outbreak of CM; a practical demonstration of the chemical exclusion result reported by Neuenschwander *et al.* (1986). CM still produces quite noticeable symptoms at the end of the dry season, but these always have to be compared to the really devastating CM infestations encountered before the release of *E. lopezi*. Memories of this initial situation seem to be dwindling.

MANAGEMENT OF OTHER CASSAVA PESTS

Despite the relative success of control of the CM with the large-scale establishment of one exotic parasitoid, the cassava crop is still faced with other severe pest problems which may require multiple introductions and establishment of several species and strains of predators and pathogens, as well as other control strategies. IITA/BCP and Centro Internacional de Agricultura Tropical (CIAT) have developed a regional project, to be sponsored by the United Nations Development Programme (UNDP), which focuses on ecologically sustainable cassava plant protection in Benin, Cameroon, Ghana and Nigeria, and Brazil. The programme's research philosophy is to identify the ecological imbalances in the system causing pest problems, and to provide environmentally and economically appropriate solutions. Consequently, the approach is interdisciplinary and multi-institutional. 'Pests' are carefully evaluated for their real pest status before extensive research commitments and control campaigns are initiated.

Biological control of the cassava green mite

Since 1984, experimental releases of several species and strains of phytoseiid mites have been carried out in different ecological zones in ten countries (J.S. Yaninek, Benin, personal communication, 1989). However, the establishment of phytoseiid mites against the CGM in Africa has been more difficult to achieve, probably due to the following factors:

(i) the natural enemy complex of mites is not well known

(ii) there has been relatively little previous work on CGM

(iii) in general, experience with biological control of mites under field conditions is lacking.

Consequently this pest has been the object of a more comprehensive pest management effort in collaboration with EMBRAPA in north-east Brazil and with CIAT. Losses have been estimated at 10-50% depending on agroecological zone, variety, planting date, planting system and length of the crop cycle. During exploration in north-east Brazil for natural enemies of the mite, CIAT and EMBRAPA observed that the most severe attacks occur in semi-arid areas. Phytoseiid natural enemies were found in only 30% of fields sampled across a range of humid to semi-arid ecological zones, and in 32% of the fields in semi-arid zones, suggesting a potential for increasing the effectiveness of local natural enemies through augmentation and conservation practices. Several species of natural enemies which have not been detected in Brazil, and some different strains of species which do occur in Brazil have been detected in homologous seasonally dry semi-arid cassava-growing areas elsewhere in South America, suggesting a potential role for classical biological control.

As many as ten different species or populations have been introduced into some countries in West, Central and East Africa. Until 1990, all released exotic phytoseiids invariably disappeared during the wet season. There may be several reasons for this. These phytoseiids may simply have become extinct when *M. tanajoa* reached the very low levels typical of the wet season. Another possibility is that these predators were ill-adapted to the climatic conditions that prevail during the wet season. Finally, combinations of these conditions may have been responsible.

Populations of the phytoseiid predator *Neoseiulus idaeus* from north-eastern Brazil have been successfully introduced into seven countries in Africa. Establishment has now been confirmed in Benin and Kenya after several cycles of potentially limiting wet and dry season conditions. An estimated 45 or more generations have now been produced in the field in both countries over a period of more than 18 months. In Benin, *N. idaeus* has become the dominant phytoseiid predator found on cassava with the tetranychid prey *M. tanajoa* and *Oligonychus gossypii.*

A pathogenic fungus with a high degree of host specificity was found attacking the mite in seasonally dry areas of Colombia, Venezuela and north-east Brazil. Feasability studies indicate that the fungus has promise as a classical biological control agent for both areas receiving between 800 and 1200 mm rainfall per year (J.S. Yaninek, unpublished data).

Control of other pests

Other pests of cassava that are being studied include the variegated grasshopper *Zonocerus variegatus*, a conspicuous pest found in the humid and sub-humid ecologies which can defoliate and kill cassava; the whitefly vector of the cassava mosaic virus, a disease estimated to cause up to 50% reduction in yield; and the larger grain borer, *Prostephanus truncatus*, an exotic pest which can cause post-harvest losses of up to 100% in maize and stored cassava chips. Several pathogenic fungi which cause varying degrees of mortality to different species of grasshoppers have been isolated and identified, and are being tested for their virulence under different conditions, so as to maximize their capabilities, under a project jointly run by IITA/BCP and the CAB International Institute of Biological Control (IIBC). From Central America, predators for the larger grain borer have been identified and are being studied for their efficiency before large-scale releases can be conducted (R.H. Markham, Benin, personal communication, 1990). One of these species, *Teretriosoma nigrescens*, has already been released in January 1991 by the Togo Crop Protection Service in collaboration with the Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ), in maize cribs. The impact of these releases is yet to be determined.

Classical biological control still continues to be pursued for the control of exotic pest species within the cassava agroecosystems. However, these efforts need to be complemented. Management strategies which have a role to play in this direction include host-plant resistance, cultural practices, and socio-economic considerations.

Host-plant resistance

Host-plant resistance and cassava pests have been studied by IITA for many years and can contribute significantly to alleviating the negative impact of several imported cassava pests. In Africa, significant resistance was found to the cassava mosaic virus vectored by whiteflies. Efforts to develop host-plant resistance to cassava green mite, whiteflies and other pests continue.

Cultural practices

The role of cultural practices in mediating cassava pest problems has recently received attention from IITA. Previous research indicated that good cassava production started with planting material free of avoidable plant pathogen and pest contaminants. Weeds, mulching, time of planting, spacing, intercrops and time of harvest have all been shown to influence the impact of a variety of cassava pests.

Recent simulation studies show that yield losses are often most severe on cassava of intermediate vigour. In general, cultural practices that enhance plant growth also increase pest numbers (e.g. cassava green mite and whitefly), but not necessarily plant damage. Conservation of phytoseiid predators of cassava green mite through maintenance of weed refuges, the creation of 'seed' plantings where high densities of phytoseiids can develop under field conditions for dissemination to the main area planting, and other available habitat management methods will be evaluated with farmers in the technology testing and adaptation phase of the project.

Socio-economic considerations

The socio-economic and political environment in cassava-growing areas influences crop production characteristics in complex ways, and hence affects the possibilities for sustainable crop production and protection practices. The links between factors such as farm size, land availability and tenure, migration patterns, gender issues, market characteristics, government agricultural policies and crop production are under investigation in several studies currently under way in Africa and South America. In Africa, IITA has several studies of this type in progress including the Rockefeller-sponsored Collaborative Study of Cassava in Africa (COSCA) Survey, an extensive survey designed to characterize the structure of cassava-based cropping systems in order to improve the relevance and impact of agricultural research on cassava in Africa, and several smaller-scale but more intensive studies in selected sites in Benin, Nigeria and Cameroon. The central figure in all these activities is our client, the farmer, without whose participation at one stage or another, our objectives cannot be fully realized. The researcher-farmer relationship in developing packages within this holistic approach therefore needs to be strengthened.

Farmer participation in biological control

Farmers are observant and rely on their own creativity to help them survive on scarce resources. However, they lack a well-developed concept of natural enemies and tend to think that all insects are harmful (Bentley & Andrews, 1991; see page 107). When farmers notice more insect pests within a few years after spraying pesticides, they assume that the insects are spontaneously generated by pesticides, not that the insecticides have wiped out the pests' natural enemies. The use of insecticides within the cassava ecosystem in Africa is minimal so these seldom affect biological control, and farmers can play an important role in the successful implementation of the classical biological control of the CM and particularly CGM. However, various difficulties were encountered.

(i) In the case of CM control, releases of the parasitoid *E. lopezi* and other beneficials were done on very few selected fields. As already mentioned, the parasitoid dispersed rapidly to cover several thousand other fields. Apart from the very few who by chance were on their farms during releases, most farmers had no knowledge of the steps taken to combat the pest. Occasionally we experienced difficulties in using farmers' fields for post-release monitoring; we were either refused entry into farms, or the crop was harvested in spite of previous promises.

(ii) During a survey to assess the economic impact of *E. lopezi* on the CM in Ghana and Côte d'Ivoire, except in very severe cases of outbreak, a number of farmers could not tell precisely when the pests arrived in their locality.

(iii) Lack of knowledge of the presence of natural enemies and the impact of pesticides used against other target pests, as in the case of the grasshopper control mentioned earlier, leads to a breakdown within the ecosystem and resurgence of the CM. Unfortunately, governments and private business have helped give farmers the world over a bias for chemical, therapeutic control, rather than non-chemical preventative control (Bentley & Andrews, 1991).

(iv) The CGM cannot be easily seen nor easily differentiated from the cassava mosaic virus (CMV) by the layman, so farmers' knowledge about this pest is almost nil. During experimental releases in Ghana, infested fields were selected, most of them without consultation with the farmers. Plants on which predacious phytoseiid mites were released were tagged to facilitate follow-up on establishment and dispersal. Later on some farmers, assuming that the tags were charms (*juju*), removed them while some of them harvested their crop before any assessment could be done, thereby making it difficult to draw conclusions on the potential of these phytoseiid species to control the pest.

Recommendations for farmer participation in biological control

Client involvement is widely regarded as useful and essential, but deep involvement of farmers is far more difficult to achieve than is usually thought. Bentley & Andrews (1991) had a lot to learn from farmers in their IPM programme for small-scale Honduran farmers, but warned that due to their incomplete knowledge and key misconceptions, farmer participation is not the key to the universe. Their participation must be evaluated in different contexts; it will prove to be useful for some purposes but inappropriate for others. In our dealing with farmers across the cassava belt of Africa, we recommend that the following steps would facilitate the implementation process:

(i) Pre-release surveys should be planned ahead by researchers and extensionists to make farmers aware of the problem being investigated, and assist them to identify pests and natural enemies and the role the latter play in populations of their hosts, in the simplest possible form.

(ii) It is expedient to involve farmers in releases and let them understand that releases in a few fields may be enough to effect control in a whole region. This will improve farmers' knowledge and contribution during the ecological and economic post-release monitoring phase. They should be made to understand that these releases may take a while for results to be seen. But once control is achieved, even if it is only a percentage of the pest controlled, it may be permanent, has no health hazards, is self-perpetuating and in the long run is cheaper. Classical biological control, as is the case with the cassava mealybug, is usually at no cost to the farmer. The farmer should therefore be made aware that it becomes more expensive for him/her to allow pesticides to destroy the natural balance being established. The farmer needs to know at this point that his/her contribution of maintaining good agronomic practices is essential to successful control. Extensionists and national research scientists need to be properly trained in order to interact effectively with farmers.

TRAINING AND NATIONAL BIOLOGICAL CONTROL PROGRAMME DEVELOPMENT

Because of the co-operation needed successfully to develop, test and implement sustainable plant protection, IITA has established a comprehensive outreach and training programme to strengthen national programmes throughout the cassava belt of Africa. The liaison between international institutes creates a bridge between national programmes isolated within continents but experiencing similar cassava production problems, and provides access to natural enemies, resistant germplasm and expertise that is essential for national programmes developing and implementing appropriate cassava plant protection technologies. The first priority has been to broaden the knowledge of national programmes in the theory and practice of sustainable plant protection through short-term group training, specialized in-country training and postgraduate training. To date, a total of 479 national programme staff have been trained in collaboration with FAO in the practical aspects of plant protection, particularly biological control, and IITA postgraduate fellows (men and women) have completed 25 MSc and 18 PhD degrees in related subjects over the past six years. Many of these training activities were supported by the UNDP.

The second priority has been to provide the logistic means needed to support specific plant protection activities in targeted countries. This includes modest, but timely, financial support from IITA to national programmes and help in arranging bilateral funding. Finally, IITA has initiated the establishment of national biological control committees to draw attention to sustainable methods of plant protection and to facilitate similar activities in the future.

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DISCUSSION

J. W. Mchowa (*Makoka Research Station, Thondwe, Malawi*). I appreciated the recommendation that control of grasshoppers using chemicals should be done on grasses to avoid disturbing the equilibrium between natural enemies and pests within the crop. But should this be carried out by governments or farmers? In Malawi, for example, farmers combating elegant grasshopper do not like to use insecticides on something which is not a crop.

W. N. O. Hammond. I think in most cases, at least in West and Central Africa, there are big government campaigns against grasshopper outbreaks. Most farmers who grow cassava in West and Central Africa cannot afford to use pesticides on this crop. They therefore depend on the national crop protection services for assistance. Our aim is to work through the government agencies. We cannot work directly with all the various farmers in the countries across this vast area.

J. W. Mchowa. Cassava is often grown in an intercropped system - would you use chemicals on crops other than cassava within that system?

W. N. O. Hammond. That is a very difficult situation: in the region in question, the Brong Ahafo in Ghana, cassava is often intercropped with tomatoes and there is usually a resurgence of the cassava mealybug where farmers have sprayed against pests on tomatoes. In this case I do not think farmers will listen if they are simply told not to spray. This remains a problem.

H. A. Sharah Uvu (*Ministry of Agriculture, Maiduguri, Borno State, Nigeria*). So far we have dealt exclusively with using natural enemies to control mealybugs in cassava. In my area, one method of control is to prune the dead tips of cassava plants. Do you encourage such agronomic practices as part of your biological control system?

W. N. O. Hammond. I did mention that there are several other control options which need to be considered. Pruning is a cultural practice which may not disturb the ecosystem. In this case it does have a place in our crop management practices.

A. A. Seif (*KARI, Nairobi, Kenya*). What is the impact of hyperparasitoids? Considering that parasites are released in different places, would hyperparasitoids not be an impediment to successful biological control?

W. N. O. Hammond. I think hyperparasitoids have a role to play in regulating pest populations. We do have problems with different species of hyperparasitoids, for example *Prochilonereus* spp. and *Chartocerus* spp.. But despite these hyperparasitoids we have observed very low mealybug populations following the release of the parasite *E. lopezi*, and in some cases these secondary parasitoids tend to have a positive effect on regulating the pest populations. Studies have shown that although a cassava mealybug larva might not have been parasitized by *E. lopezi*, its development is arrested when it is stung by the hyperparasitoid *Prochilonereus insolitus*, while searching for parasitoid larvae inside the mealybug. Another example is the case of the mango mealybug *Rastrococcus invadens* which was introduced into Africa in the early 1980s. Its primary parasitoid, when it was first released, completely wiped out the host populations and consequently temporarily eliminated itself locally. Resurgence of the pest was observed in several locations, possibly due to the absence of a strong influence of hyperparasitoids which could have kept the populations of both the pest and primary parasitoid in balance.

Management of maize and sorghum stalks and residues by small-scale farmers and its implications for IPM control strategies in Kenya

B. T. NYAMBO & M. MWANGI

International Centre for Insect Physiology and Ecology, Oyugis Sub-station, PO Box 325, Oyugis, Kenya

ABSTRACT

A study was carried out in the Oyugis and Kendu Bay divisions of South Nyanza in 1989/90 to assess the impact of the on-farm management of sorghum and maize stalks, stubble and residues on the carry-over of *Chilo partellus* and *Busseola fusca* populations, and of natural enemies associated with the immature stages of the borers. The objective was to identify potential natural enemies of the borers and areas needing further research to improve IPM recommendations. It was shown that 74.2% of the farmers have various uses for stalk, stubble and residues at the farm level, 51.2% of which goes into soil management. Burning is unpopular among farmers, being practised by only 5.8%. Several species of parasitoids identified in stalks and stubble during the off-season were also recorded on sorghum and maize stems during the cropping season, demonstrating that stalks, stubble and residues are an important sanctuary of potential natural enemies of borers. Research is needed to verify further the significance of stalks, stubble and residues as a good refuge for pests and their natural enemies, and also to identify suitable and acceptable alternative crop residue management for farmers.

RESUME

En 1989-90, une étude a été effectuée dans les divisions Oyugis et Kendu Bay du South Nyanza afin d'évaluer l'impact de l'utilisation dans les exploitations des tiges, des chaumes et des résidus de sorgho et de mais sur la perpétuation des populations de *Chilo partellus* et de *Busseola fusca* et des ennemis naturels associés aux stades immatures des déprédateurs de tiges. L'objectif était d'identifier les ennemis naturels potentiels des déprédateurs et les domaines nécessitant des recherches supplémentaires afin d'améliorer les recommandations en matière de lutte intégrée contre les fléaux. On a montré que 74,2% des paysans utilisaient de diverses manières les tiges, le chaume et les résidus dans leurs exploitations, avec 51,2% de ceux-ci incorporés à la terre. Le brûlis est impopulaire parmi les paysans et n'était pratiqué que par 5,8% seulement d'entre eux. Plusieurs espèces de parasitoides identifiés sur les tiges et dans le chaume au cours de la période finale de la campagne étaient aussi trouvées sur les tiges de sorgho et de mais au cours de la saison de culture, ce qui prouve que les tiges, le chaume et les résidus sont un sanctuaire important pour les ennemis naturels potentiels des déprédateurs. Des recherches s'avèrent nécessaires pour vérifier dans quelle mesure les tiges, le chaume et les résidus sont un bon refuge pour les ravageurs et leurs ennemis naturels et pour identifier d'autres façons de gérer les résidus de cultures qui soient appropriées et acceptables par les paysans.

INTRODUCTION

The significance of maize and sorghum stalks, stubble and residues during the off-season as potential refuge for diapausing stem borer populations has been demonstrated by many workers (Duerden, 1953; Swaine, 1957; Ingram, 1958; Mohyudin & Greathead, 1970; Unnithan & Reddy, 1989). Complete destruction of all stalks, stubble and residue has been strongly advocated as a means of reducing potential borer attack at the beginning of the growing season. Uprooting, burning or ploughing under are effective methods when applied on a large scale; however, few small-scale farmers follow this practice for the following reasons:

(i) residues have various uses on the farm, e.g. fuel, thatch, animal feed and soil conservation

(ii) chopping and ploughing under is often impractical because of resource limitation and because soils may not be workable during the dry season

(iii) burning conflicts with the principles of soil fertility and environmental conservation and can cause air pollution.

Moreover, the significance of the stalks, stubble and residues of cereal crops as potential refuge for the borers' natural enemies has not been exploited in the management of borer populations, particularly for the small-scale farmer situation, because of a lack of adequate information.

A study was done during 1989/90 in the Oyugis and Kendu Bay divisions, South Nyanza, Kenya with three objectives.

(i) To identify the indigenous natural enemies associated with the immature stages (larvae and pupae) of the stem borers on maize and sorghum stalks and stubble after harvest and during the off-season, and to monitor the activity of potential natural enemies on the cereal crops during the cropping season.

(ii) To obtain up-to-date information on management and uses of maize and sorghum stalks, stubble and residues by small-scale farmers, with emphasis on its implications for future improvement of an integrated pest management (IPM) programme for these pests.

(iii) To identify areas needing further research for the improvement of stem borer IPM.

METHODS

The study area

Oyugis division has two cropping seasons in a year: the long rainy (LR) season extends from February/March to June/July, and the short rainy (SR) season from September/October to December/January. In contrast, Kendu Bay division has only one reliable rainy season, the long rainy (LR) season from February/March to June/July followed by the long dry season from August to January.

Survey of natural enemies

Field surveys to monitor the natural enemies of *Busseola fusca* and *Chilo partellus* on maize and sorghum stalks and stubble were conducted weekly in Oyugis and Kendu Bay divisions in June to December each year. On each visit, 20 stem borer-damaged stalks or pieces of stubble were collected at random from five farms at an interval of 2 km to obtain a total of 100 stalks or stubble per visit. These were dissected and all the larvae and pupae found were collected and taken to the laboratory for observations on parasitoids and pathogens. All moribund or parasitized larvae and pupae were recorded.

To collect information on the activity of potential parasitoids during the cropping season, 50 borer-damaged stems were collected at two-week intervals. These were treated as above and the larvae/pupae recovered were taken to the laboratory for observations on parasitoids and pathogens. The larvae were maintained on a natural diet collected from the field until they pupated and emerged as adults. The pupae were held individually in small specimen vials until the adults emerged.

Parasitized specimens were recorded and the parasitoids saved for identification. Specimens suspected of being infected by pathogens were sent to the Biocontrol Unit at Mbita Point Field Station for identification.

During the field visits, observations on the management and uses of sorghum and maize stalks, stubble and residues at the farm level were made. Informal discussions on the uses of stalks, stubble and residues were held with farmers. A total of 50 farmers were involved.

RESULTS

Natural enemies

The incidence of *B. fusca* and *C. partellus* larvae and pupal parasitism and pathogens for the two years relative to the larvae and pupal populations observed are shown in Tables 1 and 2.

Table 1 Incidence of parasitism and pathogens on the immature stages of *Chilo partellus* on maize and sorghum stems, stalks and stubble in Oyugis and Kendu Bay Divisions, 1989/90

			Number of larvae recovered from maize			Number of larvae recovered from sorghum			Number of pupae	
Year	Month	Division	Collected	Parasitized	Pathogen	Collected	Parasitized	Pathogen	Collected	Parasitized
1989	June	K. Bay	0	0	0	7	0	0	0	0
	July		0	0	0	1	0	0	0	0
	Aug		0	0	0	67	7	0	0	0
	Sept		12[a]	0	0	138	3	5	1	0
	Nov		0	0	0	58	17	4	16	0
	Dec		0	0	0	45	1	1	6	0
	Aug	Oyugis	0	0	0	3	0	0	0	0
	Sept		11[b]	4	0	5	0	0	4	0
	Oct		11[b]	2	0	0	0	0	0	0
	Nov		35[b]	18	1	3	0	0	1	0
1990	April	K. Bay	8[b]	0	0	46[b]	7	0	0	0
	May		9[b]	0	0	24[b]	6	2	1	1
	June		0	0	0	2	1	0	1	1
	July		0	0	0	92	6	1	5	0
	Aug		0	0	0	40	3	8	4	0
	Sept		0	0	0	24[a]	0	0	0	0
	Oct		0	0	0	86[a]	6	7	3	0
	Nov		0	0	0	4[a]	1	2	0	0
	Dec		0	0	0	88[a]	2	1	10	1
	July	Oyugis	0	0	0	34	2	5	2	0
	Aug		0	0	0	5	0	0	2	1
	Oct		212[b]	44	13	0	0	0	5	0
	Nov		100[b]	12	2	0	0	0	3	1
	Dec		9[b]	3	0	0	0	0	1	1

[a]Larvae recovered from dry stalks or stubble and fire-cured stalks.
[b]Larvae recovered from stem during the season. The rest of the larvae were collected from standing green stalks.

Table 2 Incidence of parasitism and pathogens on the immature stages of *Busseola fusca* on maize and sorghum stems, stalks and stubble in Oyugis and Kendu Bay Divisions, 1989/90

			Number of larvae recovered from maize			Number of larvae recovered from sorghum			Number of pupae	
Year	Month	Division	Collected	Parasitized	Pathogen	Collected	Parasitized	Pathogen	Collected	Parasitized
1989	June	Oyugis	0	0	0	30	7	1	0	0
	July		0	0	0	13	1	1	0	0
	Aug		0	0	0	117	76	0	1	1
	Sept		11[b]	4	0	49[c]	30	3	1	0
	Oct		17[b]	11	0	25[c]	5	4	0	0
	Nov		13[b]	5	0	43[c]	27	0	0	0
	Dec		8[b]	2	0	0	0	0	0	0
	June	K. Bay	0	0	0	16	6	1	0	0
	July		0	0	0	28	3	0	0	0
	Aug		0	0	0	60	46	2	1	1
	Sept		4[a]	0	0	92	42	1	0	0
	Nov		0	0	0	92	55	0	3	2
	Dec		0	0	0	0	0	0	1	0
1990	Jan	Oyugis	2[b]	0	0	0	0	0	0	0
	June		0	0	0	5	0	0	0	0
	July		0	0	0	63	33	6	0	0
	Aug		0	0	0	47	17	1	1	1
	Sept		0	0	0	22[a]	6	1	0	0
	Oct		45[b]	3	2	0	0	0	0	0
	Nov		32[b]	6	1	0	0	0	0	0
	Dec		30[b]	1	1	0	0	0	1	0
	April	K. Bay	0	0	0	8[b]	2	0	0	0
	May		0	0	0	3[b]	0	0	1	1
	July		0	0	0	361	92	23	9	0
	Aug		0	0	0	60	24	0	0	0
	Sept		0	0	0	10[a]	4	0	0	0
	Oct		0	0	0	24[a]	10	8	0	0

[a]Larvae recovered from dry stalks or stubble and fire-cured stalks.
[b]Larvae recovered from stems during the season. The rest of the larvae were collected from standing green stalks.
[c]Some of the larvae were collected from stalks piled at field edge.

June to December 1989

Few *Chilo* larvae were recovered from maize and sorghum stalks and stubble in Oyugis (Table 1). Larval parasitism observed in Oyugis in October to December was mainly on larvae collected from the SR maize crop stems. Of the parasitoids recorded during this period, *Apanteles flavipes* and *A. sesamiae* (Mohyudin, 1971) were the most commonly recorded. In Kendu Bay, the majority of larvae and pupae were recovered from sorghum stalks, stubble and ratoons. The weather during 1989 was extraordinarily wet, so sorghum ratooned readily while stalks did not dry as fast. As in Oyugis, the most frequent parasitoids encountered were *A. flavipes* and *A. sesamiae*. Overall, the level of *Chilo* larval and pupal parasitism and pathogens was very low in Kendu Bay, where the population was relatively high compared to Oyugis division. *Apanteles flavipes* was the only parasitoid common to both divisions on *C. partellus* larvae. No pupal parasitoids were recorded during the period.

Parasitism on *B. fusca* larval populations was higher in both divisions (Table 2) than that observed on *C. partellus* (Tables 1 and 2). Peak parasitism in Oyugis occurred in September to October and in Kendu Bay during August. Larval populations in Oyugis during September to December included collections from the SR maize crop stems (Table 2). The most frequent parasitoid species were *A. flavipes* and *A. sesamiae* and another *Apanteles* sp. coded C in both divisions. However, whereas *A. flavipes* accounted for 32% of the total parasitoids recovered from larvae collected in Oyugis, it comprised only 10% in Kendu Bay. Similarly, *A. sesamiae* contributed 16.2% of the larval parasitism in Oyugis division and 8.8% in Kendu Bay. *Apanteles* sp. group C was not recorded in Kendu Bay. Several hyperparasitic species were recorded, mostly from Kendu Bay division. These differences could be due to differences in agroecological environmental conditions between the two divisions. One record of *Pediobius furvas* and one of an unidentified pupal parasitoid were made, both from pupae collected on sorghum stalks in Oyugis. Of diseased specimens, one larva was infected by the fungal organism *Metarhizium* (N. K. Maniania, personal communication).

April to December 1990

The incidence of stem borer infestation early in the season was low in both divisions. Only eight *B. fusca* larvae were collected from sorghum stems in April and three larvae and one pupa, also on sorghum stems in Kendu Bay during the month of May. Of those collected in April, two larvae were parasitized, one of them by a nematode. The pupa collected in May was parasitized by a gregarious parasitoid, probably *Pediobius furvus*.

Between June and August, larvae and pupae were recovered from sorghum stalks and stubble in both divisions. During the period September to December, larvae and pupae in Oyugis division were confined to the SR maize stems, whereas in Kendu Bay they were also found on sorghum stalks, stubble and ratoon sorghum.

Unlike the previous season, peak parasitism on *B. fusca* occurred in July to September in Oyugis and August to September in Kendu Bay. The level of pathogens in the population was lower compared to 1989 in both divisions, and none could be considered important. Parasitoids recorded on *B. fusca* larvae in 1989 were again recovered during 1990; *A. flavipes* and *A. sesamiae* were the most frequently encountered in Kendu Bay between July and September, and in Oyugis in July and August. *Apanteles* sp. group C was recorded in September to December in the Oyugis division only.

As observed in 1989, *C. partellus* larval parasitism was low. In Oyugis, *Apanteles* sp. group C and *A. flavipes* were the most frequent in October to December, whereas in Kendu Bay, *A. flavipes* was dominant. All the larvae collected from the dry stalks in September to December in Kendu Bay pupated within two to three weeks of feeding on fresh maize stem cuttings and emerged as adults a week after pupation.

New parasitoids were recorded during the year. In Kendu Bay, a gregarious *Bracon* sp. was recovered from *B. fusca* larvae in August near Kandiege village. Another *Bracon* sp. was recorded on *B. fusca* larvae collected from the SR maize crop in Oyugis. One record of *P. furvus* was made on *C. partellus* pupae collected from Kendu Bay. Three records of *Dentichasmias busseolae* on *C. partellus* pupae collected from sorghum were made in Kendu Bay. In Oyugis division, one record of *Gonibracon robustus*, a bracon, was made on *B. fusca* pupae collected from the SR maize crop stems.

On-farm management and uses of stalks, stubble and residues

The management and uses of sorghum and maize stalks, stubble and residues (Table 3) at the farm level varied between farms. However, the various economic uses, totalling 74.3%, are a clear indication that stalks, stubble and residues are valuable to farmers. Of the various uses, soil conservation takes up 51.2%, stressing the importance farmers attach to the need of soil conservation for continued food production. Despite the various uses, not a single farmer uproots the stalks. The common practice is to cut the stalks above ground level, the remaining part being uprooted during land preparation. Where a farmer decides to leave the field fallow for a season, for example, the sorghum stumps are allowed to ratoon as long as rainfall is not limiting. Unlike in other areas where ratoon sorghum is taken care of and harvested, the ratoons in the study area are rarely harvested. Where stalks are not cut for use on the farm as indicated in Table 3, the usual practice is to leave them in the field to dry and decompose, which is of direct benefit to the field. Where a farmer has livestock, these are allowed to graze on the stalks immediately after harvest, and what remains is then ploughed under at land preparation. This is a common practice in Kendu Bay mainly because the area has one cropping season.

A small proportion of farmers (19%) piled stalks and stubble on the edge of the field, sometimes after partial burning, often between the field boundaries where they were left to dry and decompose gradually. Occasionally some of these stalks and stubble could be collected and used by the farmer.

The relationship between the on-farm management and uses of stalks, stubble and residues, and the stem borer populations, can be summed up as follows:

(i) Standing stalks were often associated with higher proportions of live stem borer immature stages and parasitoids even when the stalks were very dry. Predators, particularly earwigs and ants, were frequently encountered on stems, stalks and stubble (Tables 1 and 2).

(ii) In Kendu Bay, both *B. fusca* and *C. partellus* larvae and pupae and their natural enemies were recovered live from fire-cured bundles of stalks and stubble reserved for firewood up to four months after they had been fire-cured. Occasionally, this may depend on the intensity of fire curing (partial burning done after harvest when the stalks are still green). Both borer immature stages and their parasitoids were destroyed.

(iii) In Oyugis, live *B. fusca* and *C. partellus* larvae and pupae and their natural enemies were recovered

Table 3 Summary of on-farm management and uses of sorghum and maize stalks, stubble and residues in Oyugis and Kendu Bay Division in 1989/90: field observations

Category	Description	Percentage of farmers involved
1	Partial burning	5.8
2	Partial ploughing under	20.3
3	Piled at field edge	19.3
4	Mulch in coffee, banana, etc.	11.6
5	Mulch in maize and sorghum	14.0
6	Construction (thatch, bathroom etc.)	4.8
7	Fencing	0.9
8	Farmyard manure and cattle feeding	4.5
9	Ratoon sorghum and fallow	10.1
10	Firewood	7.2
11	Baking pots (pot making)	0.9

from field edge stacks of stalks up to November to December, five to six months after harvest.

(iv) Depending on the amount of rainfall, maize stalks, stubble and residues used as mulch and/or piled up on the field edge can decompose rapidly, particularly if there is termite attack as well.

(v) Only rarely were live borer immature stages recovered from stalks, stubble and residues used as mulch, although parasite cocoons were found.

DISCUSSION

The findings in this study concerning on-farm management and uses of sorghum and maize stalks, stubble and residues do not differ from earlier results obtained in the same study area in 1986 (Saxena *et al.*, 1989). In the current study, based on visual observations, only 5.8% of the farmers burn stalks and stubble; according to Saxena *et al.* (1989), the results of farmers' interviews indicated that 11-15% of the farmers burned crop residues. Therefore, the recommended practice of burning stalks completely after harvest is not followed by the majority of the farmers. These findings are not unique to the study area. Work on the management of sorghum stalks and residues by small-scale farmers in West Africa (Adesiyun & Ajayi, 1980) and in Ethiopia (Gebre-Amlak, 1988) has shown that farmers are reluctant to uproot and burn the residues after harvest because the stalks have various economic uses at the farm level, a similar situation to this case study. Both workers concluded that alternative management methods should be exploited that can lead to significant reduction of the carry-over borer population as well as ensuring the farmer has a continued supply of stalks for use on the farm.

Adesiyun & Ajayi (1980) recommended partial burning of stalks immediately after harvest to kill the larvae (95% kill) which will save stalks for farmers' use. Although not all larvae will be killed by partial burning of stalks and stubble, the potential pest population would be reduced. Complete or partial burning is unpopular with farmers because what cannot be used for construction is needed for soil conservation. About 51% of the residue was observed to be used for soil management purposes in this case study. This is particularly important in Oyugis division where there is high pressure on the land and soils are being over-exploited with minimal inputs of fertilizer. Burning may also be destructive to natural enemies of the borer populations taking refuge in the stalks, stubble and residues during the off-season period.

As shown in West Africa (Adesiyun & Ajayi, 1980) and in Ethiopia (Gebre-Amlak, 1988), spreading the stalks thinly in the field is an effective alternative to partial burning in reducing carry-over borer populations. In this study, stalks, stubble and residues were spread as mulch in the fields, and there was evidence that no live larvae nor pupae were recovered from such stalks, stubble and residues several months after they had dried completely; any larvae taking refuge in the stalks are killed supposedly due to extreme fluctuations in temperature and moisture.

Allowing livestock to graze on the stalks immediately after harvest causes high larval and pupal mortality of the borer populations before the larvae can migrate to the bottom of the stem to diapause; this practice should be encouraged.

The Kendu Bay situation, notably during the 1990 season, is hard to compromise because 1990 was a typical season for the area. During the season, the dry sorghum stalks and stubble were associated with live *C. partellus* larvae and their parasitoids. The larvae resumed growth and pupated after feeding on fresh maize stem cuttings, suggesting the existence of facultative diapause in the population. The survival of such larval populations, in addition to *B.fusca* surviving in diapause at the bottom of sorghum stems, could be a potential threat to maize and sorghum in the season. However, early season observations on maize and sorghum during the 1991 LR season in the area showed that damage to the crop due to borer attack was still negligible. Therefore research to monitor and establish the fate of such larval populations and their associated natural enemies under field conditions is needed.

Although in the case study only a few of the parasitoids were found to be active on stalks and stubble during the cropping season, a contrast to the Rusinga Island situation where no parasitoids were recorded (Unnithan

& Reddy, 1989), the role of parasitoids and predators on the off-season diapausing borer population cannot be ignored even though it occurs at low levels. *C. partellus* was associated with few parasitoids, also reported at Mbita Point Field Station (Oloo & Ogeda, 1990). The spotted borer was introduced into Africa in recent years, and all of the parasitoids recorded in this case study are not specific to *C. partellus* (Mohyudin, 1968; 1971). Therefore, steps to conserve these indigenous natural enemies should be given priority in any IPM programme to improve and create a favourable environment for their survival and multiplication.

CONCLUSIONS AND SUGGESTIONS

The current sorghum and maize stubble management practices recommended to farmers should be reviewed because, although partial-to-complete burning destroys the pest populations, the disadvantages of the practice outweigh the benefits. Therefore the current practice of using stalks, stubble and residues as mulch should be encouraged, particularly in Oyugis division, as long as the mulch is thinly spread to facilitate quick drying and killing of the immature borer stages. In Kendu Bay, farmers should be encouraged to graze their livestock in the field immediately after harvest. Farmers in both divisions should be encouraged to uproot or cut stalks after harvest even where the field is intended to be left fallow in order to reduce the potential carry-over borer populations.

Further research is needed to verify the potential role of stalks, stubble and residues as a refuge for natural enemies of stem borers and how best to manage these under the small-scale farming systems typical of Africa. To avoid the traditional blanket recommendation, each situation should be analysed to identify suitable and acceptable management practices. The case study of Rusinga Island (Unnithan & Seshu Reddy, 1989) serves as a good contrast with the current study.

Research on the biology and ecology of the most frequent parasitoids is needed before these can be incorporated in the IPM practices recommended to farmers in the project area.

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DISCUSSION

P. Nkunika (*Department of Biology, University of Zambia*). Are termites also pests of maize?

B. T. Nyambo. No, but they are important in the decomposition of crop residues, affecting the speed at which the crops decompose, in some areas.

A. A. Seif (*KARI, Nairobi, Kenya*). I am concerned that you recommend not to burn or destroy stubble and residues. As you might know we often spray maize against diseases, so you can imagine what happens if you leave the stubble and the residues, there will be no maize to harvest.

B. T. Nyambo. In my talk I was dealing with our project area, where pathogens have not so far been a problem. Should a disease become a problem in the project area, I think that should also be given weight in an IPM package, and whatever pest control measures are taken should take diseases into consideration.

L. S. Diarra (*SNPV, Bamako, Mali*). How far are farmers aware of the stem borer damage, and what are the actual methods of control you would recommend farmers to adopt?

B. T. Nyambo. The farmers in our project area are quite conversant with the borers. Our control strategy is not to use pesticides at all at the moment. That is why we have come up with plant resistance, cultural practices and intercropping combinations to try to deal with the insect pests. We do not want farmers to use any pesticides because we know they cannot afford them.

G. Kibata (*NAL, Nairobi, Kenya*). There has been much discussion about natural enemies, but at present ICIPE is asking for more efficient parasites for control of borers as the ones used now have not been very effective. We do have an in-depth understanding of what is going on, but is it not true that the local parasites have not been doing a very good job? Also, instead of pesticides, could the local practices of using ash and soil applied to the plant, practices farmers have been carrying on for quite a while, not be incorporated?

B. T. Nyambo. That is a very good point. It is true that ICIPE is trying to apply exotic natural enemies to stem borers, but not in the project area studied. We are doing surveys and holding informal discussions to find out what farmers traditionally do to control some of the pests they have on their farms. I came across two occasions where farmers used ash in the crop, but more as a post-harvest treatment, not on field crops. Although there is some work on exotic parasites, we also know the importance of trying to conserve our natural parasites, which are very important in their overall influence on the pest populations.

Indigenous pest control systems and cultivation practices for resource-poor farmers

H. A. SHARAH UVU

Ministry of Agriculture, PMB 1047, Maiduguri, Borno State, Nigeria

ABSTRACT

Borno State, northern Nigeria, has an arid or savanna climate requiring irrigation or practices which maximize residual soil moisture to ensure good yields. Common crops include sorghum, maize, millet, rice, groundnut, vegetables and wheat. Common pests include grasshoppers, weaver birds and quelea, and aphids. For effective pest control, it is necessary to identify both the costs incurred by each pest, and the costs (including environmental costs) of potential control measures. The ecological conditions of the crop and the socio-economic circumstances of the farmer must also be taken into account. The various pest control practices utilized include plant breeding, cultural, biological, physical and chemical; for various reasons, the majority of resource-poor farmers would prefer to use chemical control measures, but in many cases are forced by financial constraints to revert to more traditional methods.

RESUME

L'Etat de Borno, dans le nord du Nigéria, a un climat aride ou de savane qui requière une irrigation ou des pratiques permettant de maximiser l'humidité résiduelle des sols pour assurer de bons rendements. Les cultures habituelles incluent le sorgho, le mais, le mil, le riz, l'arachide, les légumes et le blé. Les ravageurs les plus courants comprennent les sauterelles, les tisserins et les quéléas ainsi que les pucerons. Pour une lutte efficace contre les ravageurs, il est nécessaire d'identifier à la fois le coût des dommages causés par chaque ravageur et le coût des mesures de lutte possibles (y compris le coût pour l'environnement). Les conditions écologiques de la culture et les circonstances socio-économiques du paysan doivent également être prises en considération. Les diverses pratiques de lutte contre les ravageurs sont de nature phytogénétique, culturale, biologique, physique et chimique. Pour des raisons variées, la majorité des paysans disposant de peu de ressources préfèrerait utiliser des méthodes de lutte chimique mais dans de nombreux cas, à cause de limitations d'ordre financier, ils sont obligés d'avoir recours à des méthodes plus traditionnelles.

INTRODUCTION

Pests such as birds can cause extensive damage to crops and agricultural produce in many parts of the world, particularly in African countries (Bruggers & Ruelle, 1980) where pest control systems are still rudimentary. Among the most notorious indigenous pests in the tropics are quelea birds (*Quelea quelea*) (Hamza *et al.*, 1982); village weavers (*Ploceus* spp.); locusts (*Schistocerca* spp.); migratory locusts (*Locusta* spp.) and various grasshopper species such as *Oedaleus senegalensis*, *O. nigeriensis* and *Kraussaria* spp. These pests cover areas south of the Sahara region (Magor, 1974) and occupy about 20% of the land areas, affecting the economy of more than 25 African countries (De Grazio, 1978). Hamza *et al.* (1982) state that about 90% of Sudan's grain-producing areas are affected by these pests, particularly by birds.

Because of the importance and economic impact of pest damage to crop production, more than 16 African countries have formed control organizations over the past 20 years (Bruggers & Ruelle, 1980), killing approximately one billion bird pests in Africa and reducing the pest population to agriculturally tolerable levels (Fumilayo & Akande, 1979). Despite the numerous control measures employed, it has been very difficult to quantify accurately the magnitude of crop losses due to pests in the countries affected. DaCamara-Smeets (1977) and Fumilayo & Akande (1977) have collected some damage estimates for certain crops in particular regions of Chad and Nigeria. In countries like Somalia, bird pests cause up to US$ 1 million (N 10 million) losses annually (Bruggers, 1980). Studies have also been carried out in Ethiopia (Jaeger & Erickson, 1980) and other African countries.

Control measures can be effective only when the killing rate exceeds the annual mortality rate (Schurig, 1987); a proportion of those birds killed during control operations represents only that part of the population which would otherwise die from natural causes during the course of a year.

Losses of such magnitude are mostly borne by the small-scale farmers, who comprise the majority of farmers in African countries. Yields are low, on average 1.8 t/ha of grain (Ministry of Agriculture, Borno State, 1987). It is therefore most appropriate in the course of this paper to recommend simple but effective and indigenous control methods which are less of an economic drain on small-scale plantings. Farmers have tended to embark on protective measures rather than on preventative activities to reduce the pest population. In many cases, farmers are accustomed to the crop protection services being the responsibility of the Government, coupled with famine control. In short, resource-poor farmers use any available method to protect their crops from destruction, including cultural, biological or chemical methods; such a combination of methods is in fact integrated pest management (IPM).

BORNO STATE

Location and climatic conditions

Borno State, Nigeria is located between 10 and 14°N and 10 and 15°E, and comprises savanna and arid lands with temperatures of 40-45°C in the dry season and 30-35°C in the rainy season. The rainy season in the savanna (southern) part of the state normally lasts from May to September, with a rainfall of 500-1500 mm annually, while in the northern, arid part of the state the rain falls from June to August, and is 300-800 mm annually. Soil, rainfall and vegetation are interrelated. Soils may not hold moisture for a long time (aridisols), or have high moisture retention (vertisols), and plants which grow on such soils must either be of short life span, or of a hardy type which can store moisture.

Due to these climatic conditions, irrigation methods are practised to supplement the rainy season cropping, using the local *shadoof* method interspersed with modern irrigation pumps. Water is obtained from ponds, tubewells, washbores, shallow wells or boreholes. While irrigation makes possible the production of fresh food throughout the year, it also allows year-round pest and disease multiplication, as well as residual moisture cropping, practised in the vertisol-dominated areas. In addition to the indigenous pest and disease multiplication, pests may migrate in search of mates, breeding places (as for example with bird pests and locusts/grasshoppers), or food and water, or to escape competition for survival due to population explosions. When such migrations happen, it is the small-scale, resource-poor farmers who suffer most.

Common crops grown in Borno State

The major crops are related to the climatic and weather conditions of this arid area and include:

* *Sorghum bicolor* grown in the rainy season (May to December) and also under residual moisture in October to January
* millet (*Pennisetum*) grown in the rainy season (June to August) only
* maize or corn (*Zea mays*) grown June to August under rains and residual moisture in vertisol areas
* rice (*Oryza sativa*) grown from June to November under rains, also under irrigation in vertisol areas
* wheat (*Triticum aestivum*) grown from November to March by irrigation only
* groundnut (*Arachis hypogaea*) grown from June to August under rains only
* vegetables grown by irrigation under local systems, e.g. onion, tomato, eggplant, lettuce, cabbage etc. (Gibbon & Pain, 1985)

Generally about 90% of the crops grown in Borno state are rainfed. It is especially during this period that food and water availability allow pest multiplication, not only in crops but also in grasses and other natural vegetation.

Common pests in Borno State

There are numerous pests indigenous to Nigeria and other tropical areas which cause heavy losses to resource-poor farmers and are also common to Borno State. Although the control organizations pre-date the present political divisions, each year these pests have posed an insoluble problem to resource-poor farmers resulting in a constant outcry. Government pest control organizations were instituted to control these pests which threaten the livelihood of resource-poor farmers. Such noxious pests are therefore classified into major sedentary (indigenous), major migratory and minor indigenous pests.

Major sedentary (indigenous) pests include:

* *Oedaleus* species of grasshoppers, which feed on millet, sorghum and cowpea in August and September

* aphids, which feed on cowpea in September to January

* *Kraussaria* spp. of grasshoppers, *Hieroglyphus* spp., *Catantops* spp. and the red locust (*Nomadacris septemfasciata*) which feed on cowpea pods, millet, rice and sorghum in both rainy and dry seasons

* bird pests include *Ploceus cucullatus*, village weavers which feed on milky stages of various grains such as wheat, millet, sorghum and rice; *Ploceus capitalis*, *Passer luteus*, *Passer griseus*, *Quelea erythrops*, *Euplectes oryx*, *Euplectes afra*, *Bubalornis albirostris* and *Lamprotornis chalybaeus*, all sedentary bird pests which cause serious damage to cereals in the field.

Major migratory pests include:

* *Quelea quelea*, the most important migratory pest of the tropics

* sporadic migratory locusts, *Locusta migratorioides*

* *Anacridium* spp. which feed on cereals and orchards.

Minor indigenous pests include:

* beetles, e.g. *Pachnoda* spp. which feed on cowpeas and millet heads

* bugs including *Hemiptera* and *Homoptera* spp. which feed on cowpeas and other legumes (Sharah, 1986).

PARAMETERS OF PEST CONTROL SYSTEMS

Before control measures can be instituted against pests, it must be determined that the damage caused warrants expensive measures being taken against that pest. The pests' activities must have resulted in increased costs. The costs of control measures include the cost of quarantine; costs of establishing and running biological controls; and the cost of major research for determining the target of control. Others are the cost of chemical control, which apart from being financially demanding, may result in negative environmental effects; the high cost of equipment; and the expense of establishing new plant cultivars which are resistant to pest and diseases.

The definition of a pest is therefore based on economics. A pest is an animal or plant which, after reaching a certain population density (the economic injury level), is capable of causing economic loss. If such a population is left uncontrolled and passes this economic threshold (Hill & Waller, 1982), the farmer is bound to suffer yield losses.

The pest populations in Borno State have two peak periods: the rainy season, and when the residual moisture crops and the wheat start to head between November and March. These are also periods when pest control is concentrated, and the measures instituted are linked with the cultivation periods and practices. Pest damage to crops comes in two different forms: direct damage caused by pests feeding on plant parts; and indirect damage caused by pests creating an opening for secondary infections on the plants.

Pest forecasting is the backbone of successful pest control. This entails a proper and detailed knowledge of the biology and ecology of the pest concerned. Accurate pest forecasting cannot be easily achieved, as it involves several natural parameters. Methods commonly used include quantitative seasonal studies based on several years' records of outbreaks which relate to climate, weather and topographical data. Life history studies may, for example, be based on egg-pod surveys which include the number of viable eggs, developmental period, food consumption and period of female development. Weather parameters affect pests directly (harsh weather can affect pest numbers), and also indirectly by affecting the host plants, predators and parasites. Pest spread is also affected by the weather. Other forecasting methods are by emergence or occurrence warning, insect monitoring, forecasting by sampling, for example by light traps, forecasting by prediction (mapping out regions of natural, occasional and possible abundance) and lastly, forecasting through experience (see Figures 1 and 2), which is the most reliable approach.

PEST CONTROL PRACTICES

Many factors influence the choice of pest control methods in the control of indigenous pests. These factors are dependent upon the conditions under which the crop is grown, the pest density, the biology of the pest, and the presence of other pests (pest complex). Some methods can more easily be incorporated into the agricultural practices than others. Economic factors (resource availability) are important. Other factors include the level of crop maturity; the stages of pest development; the intensity and extent of the pest outbreak; the system of farming practised; manpower availability; and the proximity of the pest outbreak site to drinking water, human and animal settlements.

Pest control systems commonly used are mostly dependent on the cultivation systems and can be classified into non-chemical and chemical methods.

Non-chemical methods

Breeding for resistance or tolerance

Breeding is mostly carried out by researchers; an example is the development of special hairy millet (*Pennisetum*) heads through selection as a repellent against quelea birds. This cultivar of *Pennisetum* has become preferred by many farmers to the more susceptible cultivars. However, varieties or cultivars which

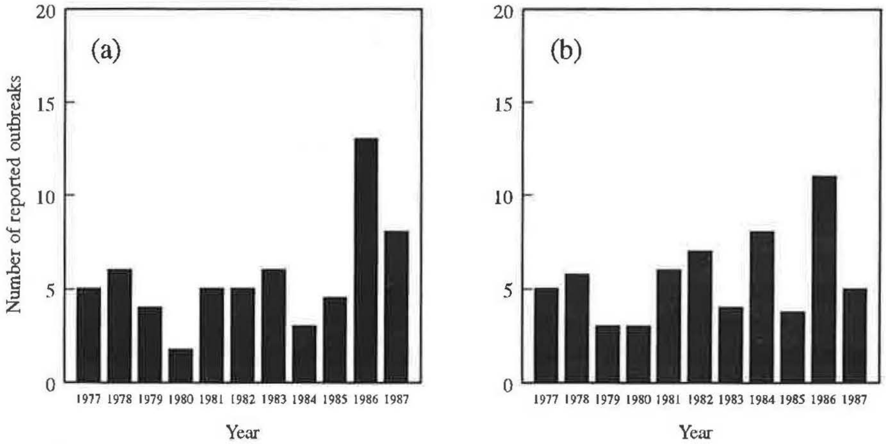

Figure 1 Histograms showing numbers of pest outbreaks recorded in Borno State between 1977 and 1987. (a) Grasshopper/locust; (b) *Quelea quelea*.

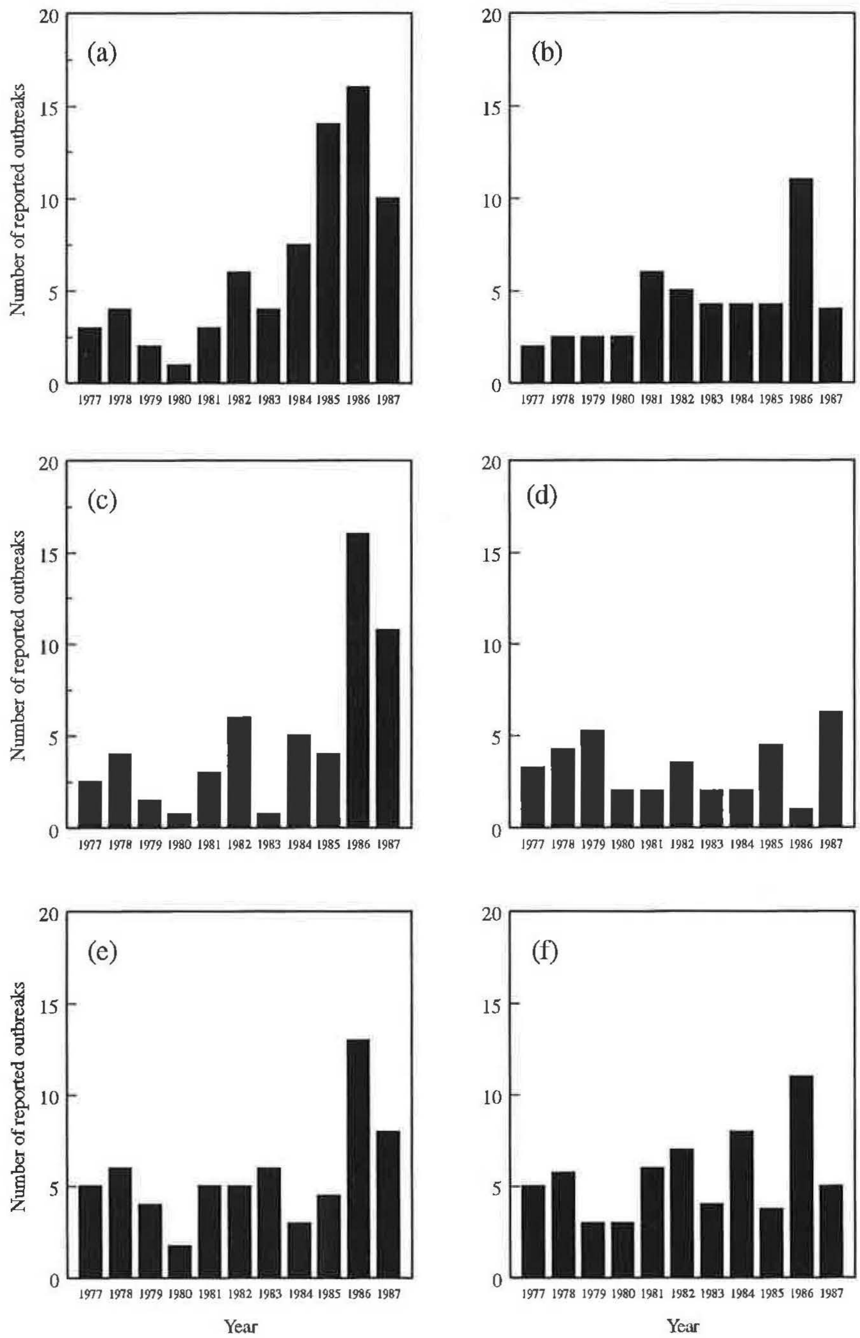

Figure 2 Histograms showing numbers of pest outbreaks recorded in Borno State between 1977 and 1987. (a) Rodents; (b) armyworm; (c) termites; (d) aphids; (e) weevil blister beetles; (f) other pests - whitefly, *Dysdercus* spp., cotton bollworms, *Podacrica* spp., *Pachnoda* spp., etc.·

seem initially to be resistant may fail after some seasons, and it may be more realistic to speak of greater tolerance of plants to pest attack. In the absence of the preferred plant, a pest may revert to the less-preferred crop as an alternative food. For example, millet is preferred to *Sorghum sudanensis* and grass seeds by quelea birds.

Resource-poor farmers are aware of these methods and have taken notice, but the problem is the suitability and palatability of such pest-tolerant crops, both to farmers and to consumers in general.

Cultural control

Cultural systems of pest control fall into two categories: direct and indirect.

Direct cultural control is the use of cultural practices to destroy the pest, such as by hand picking or mechanical crushing, as practised for armyworms, grasshoppers and locust nymphs. Light traps or fruit traps are also used to attract flying insects in the dark; chemicals or fire are then used to destroy them. Sticky bands around tree trunks help in preventing caterpillars from climbing and destroying tree crops; the caterpillars can later be collected and destroyed. An old method which is still used today in the tropics is to dig a trench across the path of moving armyworm or locust bands and, after the bands have fallen into the holes, to bury them. In some areas the trenches are filled with water and serve as traps for the crawling pests.

In rodent control, the use of tempting food traps placed in a pit or large buried pot has proved successful. The rats or mice move into the pots or sacks with the bait to feed and are unable to find their way out. They can later be killed, collected and used as delicacies. Direct killing of pests such as grasshoppers by the use of light traps, and of rodents using both light traps and non-poisonous traps to provide delicacies, is now being promoted by a popular campaign in the tropical world to offset the costs of control. Direct cultural control of birds can also provide a good source of cheap protein, and is welcomed by many communities.

Physical control is another non-chemical approach, but seems to be far-fetched in our society, particularly for resource-poor farmers. One of the few physical means resource-poor farmers have access to is heat, and pests have largely become adapted to natural heat. Farmers do expose corn stalks or set fire to those unwanted during land preparation: this is actually done for reasons other than pest control, but has turned out to be a useful practice. In the same way, barns are cleaned and dusted with local ashes, or exposed to the sun for some time before storing the new produce. The aim is to clean the barn of dirt and not pests, but this also serves as another way of controlling storage pests.

Indirect cultural control involves the use of conventional methods, such as scaring, particularly for bird pests and for flying locusts and grasshoppers. This method does not kill the pests, but banishes them from the vicinity of the crop. This is crop protection rather than pest control. Planting early and harvesting early after successfully studying the biology of the pests in question is also providing results. Removal of alternative hosts, use of closed seasons, crop rotation, trap crops, dry-season cultivation, clean seed materials, crop spacing and rogueing are all indirect cultural pest control methods of which farmers are now aware and which are being practised. Although resource-poor farmers have been using such methods for generations, they need education to intensify the practice. This is clearly demonstrated in the histograms (Figures 1 and 2) of pest outbreaks. Farmers tend not to report minor pest outbreaks unless the outbreak reaches a magnitude which they cannot tackle locally.

On the other hand the major migratory pests (locusts/grasshoppers and *Quelea quelea*, for example) have continued to increase - the farmers' control measures scared them into nesting or roosting in inaccessible sites, and only going onto farm land to feed. The farmers now have to report to the control authority, who later take action through aerial control, using poisonous chemicals as a last resort. In areas accessible on foot, chemical ground operations are carried out. The reason for such emphasis on killing locusts, grasshoppers and quelea birds is that indirect control measures (scaring, drumming, caterpaulting) give only temporary control and require continuous effort to be effective, including even that of the smallest member of the family from perhaps as early as 5 am each day.

Biological control

This is a further non-chemical method, involving the use of one life to destroy another (e.g. hawks and snakes feeding on grasshoppers, rodents and birds). Humans, as mentioned earlier, use this method when killing pests which can be used for food.

Chemical control

The other class of pest control method is chemical control. However, resource-poor farmers are generally limited to the natural, physical, cultural and biological controls - expensive chemical controls are used only as a last resort or when the control authority can afford to offer assistance. The resource-poor farmers with their small farms have rudimentary cultivation methods which are linked to the availability of the resources at hand. These farmers, who form the backbone (80% or more) of the world's food suppliers, cannot afford sophisticated chemicals. The use of chemicals to control pests in this part of the world by the control authorities is necessitated by the famine threats posed by such pests as locusts, grasshoppers and quelea birds. These flying pests are particularly difficult to control. In this case the non-chemical methods mentioned above can only be a rudimentary attempt to offer a level of protection, whereas the chemical approach is a more or less destructive control method. Non-chemical crop protection is limited, and its effects cannot last as long as chemical control. Resource-poor farmers prefer to see pests physically dead, and not to talk of 'repellants', 'antifeedants' or 'protectants'. Such farmers prefer the poisonous chemical groups: fumigants, residuals, systemics and eradicants. The other problem with resource-poor farmers is that they tend to have a fixed opinion on a particular chemical based either on its colour after or before dilution, on its smell, or on another farmer's experience with that particular chemical. They do not take into consideration the farming practices, pest type or crop type, or take time to observe the chemical's action after spraying.

OBSERVATIONS ON THE EFFICACY OF CONTROL PRACTICES FOR RESOURCE-POOR FARMERS

In areas where pest outbreaks are complex and farmers need to control pests, IPM becomes important, using all the available control methods mentioned above combined as necessary to protect the crop. Pests are generally difficult or impossible to eradicate, so they have to be managed in any combination of ways possible. The resource-poor farmers' aim is to reduce the pest population locally or to protect their farms locally from such populations. They choose direct or indirect cultural methods first, later supplemented by the control authorities and any natural methods available within their limited resources. Resource-poor farmers will try to alleviate their own problems and not those of their closest neighbours: they want total pest eradication rather than management, and believe these pests should not appear at all on their farms.

In a nutshell, resource-poor farmers, with their seasonal cultivation systems, are not in agreement with the philosophy and characteristics of pest management. Their pest problems are seasonal, pests are only tackled on arrival, and on the spot. To the resource-poor farmer, the problem is the impossibility of crop pest eradication in the tropical world. The cultivation systems of the developing countries are turning from small-scale to large-scale, and in addition the use of water management for irrigation purposes is increasing. This increases the humidity, making the environmental conditions more favourable for pest and disease multiplication.

Experience has also shown that the pest population has increased almost tenfold since the declaration that agricultural development cannot be achieved without incorporating irrigation practices as a policy for crop production. This policy, which has put all arable land under crop coverage all year round, has not only encouraged crop production, but also pest reproduction and multiplication. In this situation, for the Government to increase the pest control allocation, chemical control was seen as the only alternative. Chemical control has both advantages and disadvantages. For long-lasting control, chemical methods are the best, they give a visible result of dead pests, and the pest population is reduced within a very short control period, which is consonant with the resource-poor farmer's wishes. Disadvantages are that chemical pesticides may be poisonous and dangerous. The environment is affected as chemicals pollute the air and water, thus causing death to non-target animals and plants.

Because of the rainfed cultivation practices, and the increasing use of irrigation in order to produce more food, there is no long-term planning for pest control (only the fire-brigade approach). Despite the increased threat posed by pests, there is little or no budgetary provision for pest control. Such unplanned and uncontrolled cultivation practices and rudimentary pest control systems have allowed the pests to multiply to uncontrolled population levels. The Government needed to engage in a mass control programme through the pest control organization of the Ministries of Agriculture. The systems used vary, and have to be adapted to the pest in question. The use of ground spraying against pests was the order of the day until aerial spraying was introduced. Resource-poor farmers have observed that spraying chemicals was more effective and long lasting. But such spraying has only received the attention of the Government as target sprays because of the cost, the scattered nature of farms, and their small size. The other type of control is to attack the hatching, roosting and nesting sites of birds, instead of their feeding place (the crop); this method contrasts with the locust and grasshopper operations, which can be carried out on a wider scale, even when the pests are feeding or flying.

CONCLUSIONS

The definition of a pest in the context of the resource-poor farmer is based on the damage caused, their nuisance to human and animal lives, and the level of pest population which, at economic injury level, poses a threat to the farmer's livelihood.

In carrying out pest control, it is important to consider the economics of the pest, the role of economics in planning for control, and also in choosing which control method to use. In choosing control methods there are several things to consider, such as the cost/benefit ratio, crop value, cost of control in relation to the damage inflicted, and timing of control in relation to crop stage, pest population density and stages of development. But resource-poor farmers have little knowledge as to the value of timing control in order to achieve the desired result.

Farmers are aware of the two approaches to control, non-chemical and chemical, but the majority of farmers prefer chemical methods - non-chemical methods are labour-intensive, achieve only limited results, and are not as long-lasting as chemical. It is generally agreed by farmers that the chemical methods involve danger coupled with high cost but, because of a preconceived desire for on-the-spot results, they still prefer the chemical approach at all costs.

The cultivation practices of resource-poor farmers are also dictated by politics. However, although farmers are very aware of this, they have not changed their minds about the difficulty, cost and dangers inherent in chemical pesticides in comparison with other control methods. A programme is being developed in Nigeria to involve farmers in the practical problems, so that they can come to appreciate the actual problems and the importance of the pest control practices in relation to their cultivation systems.

Also, a media enlightenment campaign is on the air, to publicize the desire of the pest control organization to form the current small-scale pest control into an institutionalized system throughout the whole state, and throughout the nation at large. This is because the pest control programmes are becoming too expensive for the State Government to bear alone.

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DISCUSSION

W. N. O. Hammond (*IITA Biological Control Centre for Africa, Benin*). The first comment I would like to make is that we really need to use standardized definitions to avoid confusion, and to be able to communicate effectively with our colleagues. The term 'biological control' is used here, but there is no mention of natural enemies or anything other than human beings killing pests. I think we need to differentiate very clearly between cultural and biological control.

The topic under discussion is indigenous pest control, and I want to find out from the speaker whether the use of methods such as neem, ashes etc, exists in his experience, in his part of Africa?

I would also like to protest that chemical control cannot be described as long-lasting. For the record, I would like it noted that this is one method which, when used, can never attain sustainability - this is why we are trying to avoid it, apart from the other problems it imposes on our environment.

H. A. Sharah Uvu. I will begin with the question of chemical control: it is long-lasting to the farmers' perspective, because the farmer wants to see results immediately, within the shortest time from applying the chemicals.

Where I come from, the insect pests themselves feed on neem, and when there is a lack of food, as I mentioned, they go back to feed on the crop sprayed with neem solution. We are currently working on this with the Agricultural Development Programme of Borno State, and so I did not include this topic in my paper.

The definition of biological control is known by almost everybody. Both human beings and animals are used to help control pests in our environment, to suit our farmers who are poor. I did not want to go into detail on technical or intellectual definitions of biological control: as I mentioned earlier, my discussion is based on practical field experience.

J. E. Ohabuike (*Lake Chad Basin Commission, Republic of Chad*). I have been working in this region for over 20 years, carrying out pest control activities, and would like to add a number of comments. First of all, we must understand that in this region of Africa, Nigeria is one of the largest countries, and has a very large population. Due to population pressure, land is a scarce commodity, especially cultivable land. The resulting intensification may be responsible for the large variety of crops on a particular piece of land; perhaps this is the reason why most farmers depend on intensive use of chemicals. However, the nature of the land, as the speaker pointed out, is such that use of chemicals may be limited. I agree that the countries around might be poor, and in getting produce and chemicals they depend mostly on foreign aid. By the time the chemicals are received it may already be too late, and crops are lost, leading to degradation of the land. Sometimes if chemicals arrive early on the farmer's site, the farmer has to store them and by the time they are used they have deteriorated. The effectiveness of chemicals is further reduced and their effect on the pest or predator is far more reduced. So we have a situation where perhaps half the insect population we want to control will be controlled, which perhaps gives the opportunity for predators to be active.

Quelea pests are very difficult to control either by chemical or natural means. The land is most often black clay, and once you have had the first and second rains, the area becomes flooded - vehicles cannot get through, the workers have to get to roosting and nesting sites on foot, and are unable to carry enough chemicals. Governments and plant protection services may only be able to use helicopters or aircraft, treating the roosting site at night, which of course is risky.

Government policy may, to some extent, be responsible for the population explosion of pests; in Nigeria, for example, they have changed to a system whereby everybody is now able to grow crops and feed his/her family, as food importation is now limited. There is no hard currency to spend on importation of food. This is true not only in Nigeria, but throughout the whole of the Lake Chad Basin sub-region where I operate. Even the ministers leave their offices to go into the field and cultivate, just to get enough to sustain their families. So pest populations are rising and pests are becoming more diverse. However, there are many other factors involved. For example, the *Quelea* birds have a very large breeding area in Cameroon, in the Waza Game Reserve. This is a very extensive reserve for all animals, and the Government of Cameroon will not allow spraying. Personally I am against the use of chemicals in that particular area - chemicals would change the balance, and the forest is a large reserve for biocontrol agents.

As far as chemical control is concerned, this is really not used much in the West African sub-region. People are now depending much more on the use of their own initiative, for example to dig holes to trap rodents. About three years ago the Government offered payment for people to catch rats, the payment depending on the number of rats' tails presented. So people went into the field and caught the rats, cut off their tails, and presented the tails for their prizes. That is the sort of cultural control that is recommendable. There are a large range of methods used by local farmers because they cannot get the chemicals and because even when they can get chemicals, they are very expensive.

Innovations in biological control

B. VERACHTERT

Plant Genetic Systems NV, J. Plateaustraat 22, B-9000 Ghent, Belgium

ABSTRACT

During the last decade, the tools of biotechnology have enabled scientists to introduce genetic resistance against a number of diseases and pests into certain crop plants. Although these technologies were mainly developed in the industrialized world, their value and impact for the improvement of agriculture in developing countries may be dramatic. Getting the technology to resource-poor farmers in the form of improved germplasm is essential to agricultural development programmes. Strategies are being designed to obtain crop protection against insects, viruses, fungi, nematodes and bacterial diseases. A programme for the genetic engineering of crop plants for insect resistance is complex and starts with the identification and isolation of genes which code for proteins with insecticidal properties. Over the past few decades, *Bacillus thuringiensis* (Bt) has been widely studied for its specific insecticidal properties targeted against a very narrow spectrum of insects. *B. thuringiensis* is totally harmless for non-target organisms, including humans. Its insecticidal properties are due to the insecticidal crystal proteins (ICPs) which are coded for by so-called *Cry* genes. Many members of this class of genes have been cloned and characterized. Based on biochemical information, isogenic strains (with respect to toxin genes) can easily be identified from a collection of Bt isolates. As for any other insecticide, it is possible that the target insect may become resistant against an ICP. The mode of action works as part of a strategy to avoid insect resistance against ICPs. Expression technology is very critical in the case of the *Bt* gene. A number of specific modifications in the coding sequences of the *Bt* gene can improve its expression levels. The preferential expression of Bt to certain specific plant tissues or organs can be regulated by using the proper promoter. Studies of insect ecology and feeding behaviour can make a useful contribution to identifying the proper promoter. Suitable gene constructs containing the *Bt* gene of interest can then be introduced into the genome of a crop plant by a transformation procedure. These transgenic plants can be used in a breeding programme for insect resistance. In any strategy to improve agricultural output, seeds will always be a critical component. Improved farming techniques, agrochemicals and machinery are only as effective as the germplasm they support. Farmers in the developing world therefore require a secured source of quality seed. Technology transfer is not an end in itself; the point is rather to ensure that farmers have access to seed of the necessary quality and quantity.

RESUME

Au cours de la dernière décennie, les outils de la biotechnologie ont permis aux chercheurs d'introduire une résistance génétique contre un certain nombre de maladies et de ravageurs dans certaines plantes cultivées. Bien que ces technologies aient été principalement mises au point dans le monde industrialisé, leur valeur et leur impact pour l'amélioration de l'agriculture dans les pays en développement peuvent être spectaculaires. Il est essentiel pour les programmes de développement agricole de transmettre la technologie aux paysans disposant de peu de ressources sous la forme de plasma germinatif amélioré. Des stratégies sont en train d'être mises au point afin d'obtenir une protection des cultures contre des insectes, des virus, des champignons, des nématodes et des maladies bactériennes. Un programme d'ingéniérie génétique visant à rendre les cultures résistantes aux insectes est complexe et débute avec l'identification et l'isolation des gènes qui codent les protéines comportant des propriétés insecticides. Durant les dernières décennies, *Bacillus thuringiensis* (Bt) a été étudié de façon approfondie pour ses propriétés insecticides spécifiques visant un spectre très limité d'insectes. *B. thuringiensis* est tout à fait inoffensif pour les organismes non visés, l'Homme y compris. Ses propriétés insecticides sont dûes à des protéines cristallines insecticides (PCI) qui sont codées par des gènes appelés "*Cry*". Un grand nombre de cette catégorie de gènes a été cloné et caractérisé. D'après l'information biochimique, les souches isogènes (en ce qui concerne les gènes des toxines) peuvent être facilement identifiées à partir d'une collection d'isolats de Bt. Comme pour tout autre insecticide, il est possible que l'insecte cible devienne résistant aux PCI. Le mode d'action fonctionne en tant que partie d'une stratégie visant à éviter la résistance de l'insecte aux PCI. La technologie d'expression est cruciale dans le cas du gène de *Bt*. Un certain nombre de modifications spécifiques dans les séquences de codage du gène *Bt* peut améliorer ses niveaux d'expression. L'expression préférentielle de Bt à certains tissus ou organes végétaux spécifiques peut être régulée en utilisant le promoteur approprié. Des études sur l'écologie des insectes et leur comportement alimentaire peuvent contribuer à identifier le promoteur approprié. Des constructions génétiques appropriées, contenant le gène de *Bt* qui nous intéresse, peuvent alors être introduites dans le génome d'une plante cultivée grâce à un processus de transformation. Ces plantes à mutation génétique peuvent être utilisées dans un programme de sélection pour la résistance aux insectes. Les semences seront toujours un élément essentiel de toute stratégie visant à améliorer la production agricole. Les techniques agricoles, les produits agrochimiques et les machines agricoles améliorés ne seront aussi efficaces que le

plasma germinatif qu'ils soutiennent. Dans le monde en développement, les paysans requièrent, par conséquent, une source fiable de semences de qualité. Le transfert de technologie n'est pas une fin en soi, il faut plutôt garantir que les paysans aient accès à des semences de qualité en quantité suffisante.

INTRODUCTION

Plant Genetic Systems is a biotechnology company located in Belgium. Its main clients are in western Europe, the USA and Japan; it has no major clients in developing countries. There are two main reasons for this: firstly, the large seed companies are located in the industrialized world, and secondly, in the western countries patent protection can be obtained. But we believe that biotechnology has much to offer the developing countries.

Benefits of resistance

The major benefit of insect-resistant crops is of course the reduction in the use of chemical insecticides, which also benefits the environment. Especially in the context of developing countries, the reduction of the use of insecticides and other pesticides is very relevant; as mentioned by the previous speaker, the costs of production, transportation, storage, distribution and application of the insecticides will all be reduced if pest-resistant crops are available.

INSECT RESISTANCE

A major method of control is based on the bacterium *Bacillus thuringiensis* (Bt), which is found all over the world. The bacteria produce crystals which contain a protein with insecticidal properties (Figure 1). It is rather a large protein, typically about 130-140 kDa in size, and consists of a head piece and a tail piece. Once the bacteria are ingested by the insect, proteases (enzymes present in the mid-gut of the insect) will process the protoxin and in effect split it in two halves. The tail part goes its own way and the head part, the actual toxin, attacks the mid-gut of the insect, eventually leading to the death of the insect.

Insecticidal crystal proteins

There are four major classes of these so-called insecticidal crystal proteins (ICPs) (Höfte & Whiteley, 1989).

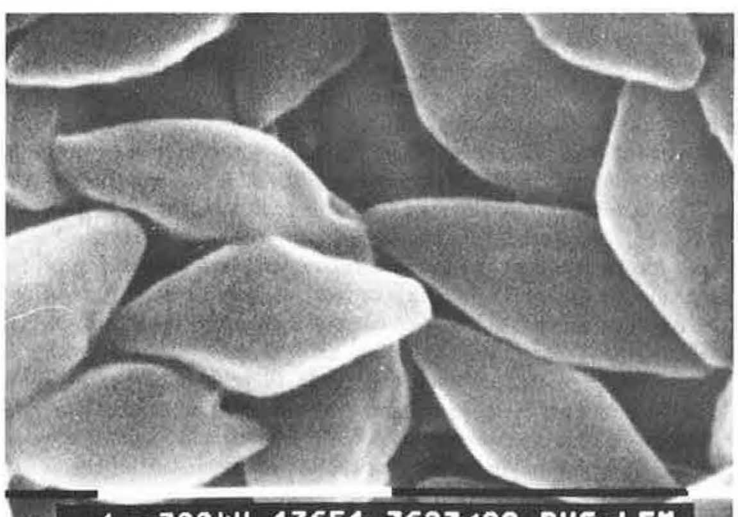

Figure 1. Electron micrograph of the bipyramidal crystals (CryIIIC) of *Bacillus thuringiensis*. Scale bar, 1 μm.

Figure 2. Control (left) and transgenic (right) potato tubers expressing a crystal protein after infestation with the potato tuber moth *Phthorimaea operculella.*

The first class of crystal proteins shows activity against the Lepidoptera; the second class shows activity against Lepidoptera and also Diptera; the third shows activity against coleopterans or beetles; and the fourth only against the dipterans.

Within each class are subspecies. For instance within the crystal protein class I, are sub-classes Ia, Ib, Ic, Id and Ie, and within these there are further sub-classes a, b, c, and so forth. Each insect is sensitive only to a narrow spectrum of Bt proteins, and the spectrum is different for each insect. This is one of the main advantages of the Bt system - it enables a single species or only a very narrow spectrum of insect species to be singled out, doing no harm to other insects or to any other animals, including mammals and human beings.

The insecticidal properties of these Bt strains have been known since the beginning of this century. In the last few decades Bt has been used effectively as a spray in a number of crops. At the beginning of the 1980s, tests for transformation procedures became available for plants, enabling the introduction of foreign genes into the plant genome. One of the first genes to be introduced into a plant was the *Bt* gene, which was introduced into a tobacco plant (Vaeck *et al.*, 1987). The gene is taken from the Bt strain and introduced into the plant, which will express the *Bt* gene and produce the Bt protein, a toxin to certain insects. The same procedure has been repeated for some other crops, including cotton, potato and tomato. Figure 2 shows damage caused in potato tubers by the potato tuber moth *Phthorimaea operculella* (left), and tubers from plants expressing the *Bt* gene (right).

Control programme

While the principle is simple, the practice is more complex. An insect control programme based on the Bt system has a number of requirements. Firstly the particular Bt strain which contains the specific crystal protein must be identified. This is not a simple task: Bt's very narrow spectrum can become a disadvantage if the required Bt strain or protein is not available. For example, Plant Genetic Systems has a large screening programme, and to date has more than 10 000 Bt isolates available.

Once the proper Bt strain has been identified, we need to isolate the specific gene which codes for the crystal protein, using a number of molecular tools. The gene itself then needs to be presented to the plant genome in such a way that the plant genome will accept and express the gene. It is necessary to adjust the gene at the molecular level so that it will become suitable for expression within plants. Also needed is a promoter, the key which will turn the gene on or off, and a transformation system. I have mentioned potato, tomato and cotton as crops for which suitable transformation systems are available, but for a number of other crops, especially those which are of importance in developing countries such as cassava and cowpea, no efficient transformation systems are available.

As an example of the complexity of the system, Figure 3 shows the histopathological effects of Bt on the midgut of an insect, in this case *Manduca sexta* (the tobacco hornworm). Figure 3A shows the intact epithelial cells of a healthy insect; Figure 3B shows the insect's midgut four hours after intoxication. The cells are totally disrupted: the microvilli have disappeared, and cells are swollen and will burst. The insect will die shortly afterwards. Using an immunocytochemistry technique, the point where the Bt toxin binds to the insect midgut can be visualized as a dark staining. The toxins bind to the microvilli and to the peritrophic membrane. Such information, combined with other morphological, physiological and biochemical data, has enabled us to determine that the Bt crystal protein binds onto a membrane receptor in the insect's midgut. The receptor binding determines the specificity of the crystal protein.

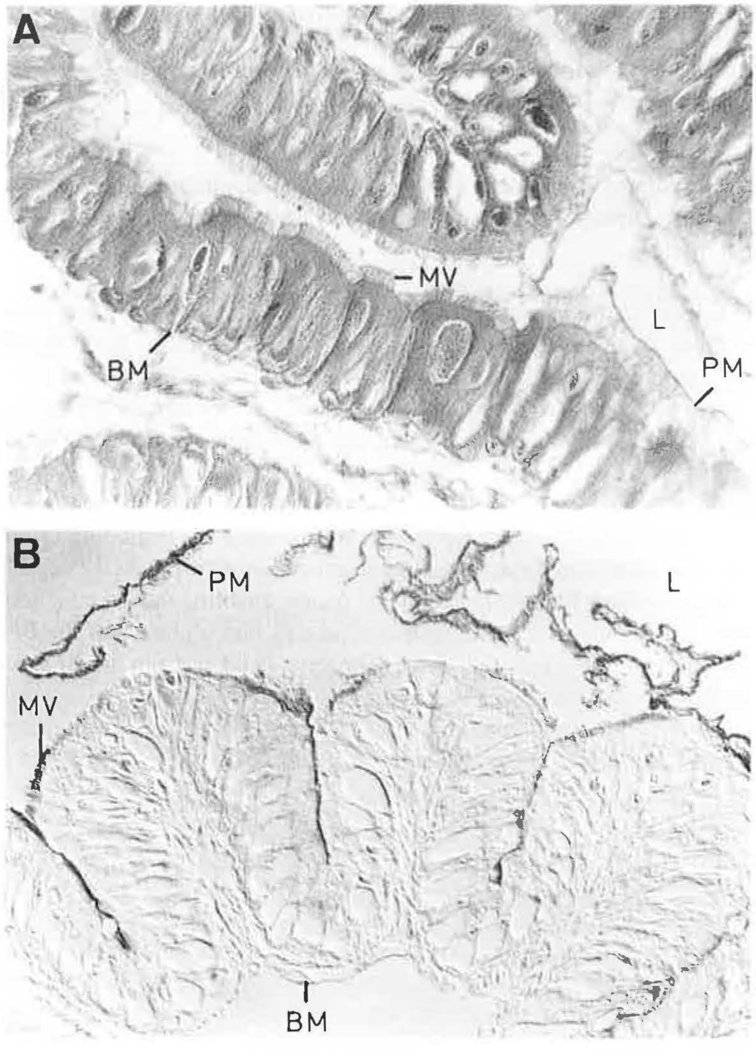

Figure 3 Histopathological effects induced by Bt toxin in the midgut of *Manduca sexta* after 4 hours. (A) Intact epithelial cells of healthy insect. Tissue section was stained with Heidenhain's Azan staining. (B) Damaged epithelial cells of intoxicated insect. The toxin is immunolocalized at the microvilli and at the peritrophic membrane (see dark staining). Light micrograph under Normarski differential interference contrast.

Future strategies

Through this kind of research, mechanisms and strategies can be developed which will at least delay the development of insect resistance against Bt; however it can be anticipated that after prolonged use insects may become resistant against the crystal proteins. Through understanding this mechanism we will in the future be able to design strategies to delay the development of resistance.

In some cases resistant strains can be obtained (McCaughey, 1985). The resistant strains remain present but the insect is no longer sensitive to crystal protein 1a, because the crystal protein does not find a suitable membrane receptor in the mid-gut. So although the insect has lost its sensitivity to one particular species of Bt crystal protein, it may remain sensitive to another Bt protein. This knowledge enables us to design proper strategies, for instance planting a crop containing crystal protein Ia one year, and then following on with the same crop containing crystal protein Ic the next year . Or a crop could contain both crystal proteins at the same time, so even if the insect loses sensitivity to one particular crystal protein, it remains sensitive to another.

FIELD TRIALS

The system presented above seems very elegant, but the real test is in the field. Even if in laboratory conditions a certain crop or plant performs extremely well, this is no real indication of how it will perform in the field. For example, field trials have been performed in the USA with insect-resistant tobacco plants which showed moderate to good resistance to the tobacco hornworm in the greenhouse. In the field, these plants showed not moderate to good, but extremely good resistance - in the field (as in the greenhouse) only part of the pest population was killed outright, but those insects not killed were apparently much more sensitive to predators and parasites, with the effect that virtually the whole pest population was eliminated. In this case, the insect-resistant plant and the natural insect predators and parasites were working synergistically.

It should be noted that field trials with transgenic plants are subject to severe regulations and must be approved by the regulatory authorities.

NEMATODE RESISTANCE

A strategy to introduce nematode resistance into crop plants must be developed at the plant-nematode interaction level. Nematicides are very expensive and are extremely toxic not only to nematodes, but also to the environment and to other animals, and are likely to be banned in the future, at least in western Europe. An alternative is therefore vital, and plant engineering may be a useful route. We are looking for proteins, similar to Bt proteins, which will show toxicity against the nematodes, and which could be introduced into plants. Candidate proteins are chitinases or collaginases; in some cases even Bt has been shown to have nematicidal properties.

Another strategy which might work in a plant-nematode interaction is to try to prevent the development of the giant cells within the plant upon which plant parasitic nematodes feed and within which they reproduce.

RESISTANCE TO BACTERIAL DISEASES

For bacterial diseases, use can be made of peptides that can be isolated from insects, which apparently give insects protection against bacterial diseases. These peptides, or at least the genes which code for these peptides, can be introduced into plants such as tobacco.

The same principles described above for insects, nematodes and bacterial diseases can also be applied to fungal diseases, or viral diseases.

TECHNOLOGY FOR DEVELOPING COUNTRIES

The technology illustrated above is very complex and expensive, and takes many years to develop. At Plant Genetic Systems, we have had experience in working with developing countries, mainly with the centres of the Consultative Group on International Agricultural Research (CGIAR).

For example, we are about to start a three-year collaboration with Centro Internacional de la Papa (CIP) on the development of insect-resistant potato lines. The potato germplasm will be provided by CIP, but the genes and the gene technology which we need, in this case the Bt technology, will be provided by Plant Genetic Systems. Much of this technology is protected through patents, but it can still be made available for use in developing countries. Free licence will be given to CIP to use the technology for its own purposes in developing countries; in this way CIP will be able to provide resource-poor farmers in developing countries with improved germplasm, containing genes which will enable the germplasm to protect itself against insect attack. We do also recognize and support the need for a centre such as CIP to provide its client countries with classically produced material.

In this way we feel that both parties can gain. On the one hand the centre, for example CIP, will gain access to expensive technology which it would otherwise have great problems obtaining. Plant Genetic Systems will gain an opportunity for our system to be used and developed in broader germplasm than we normally have access to.

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DISCUSSION

J. W. Mchowa (*Makoka Research Station, Thondwe, Malawi*). You state that what kills the insect is a toxin with insecticidal properties, and you plan to manufacture this, yet you do not know the effect of this toxin on humans. The plant manufactures the toxin which will break down like a chemical insecticide, so that people eating the food produced are eating the toxin. Do you think it is more dangerous than spraying chemicals in that sense? Can the toxin have an effect on humans?

B. Verachtert. As I mentioned, Bt has been used as a spray for some decades now, and its safety record is extremely good. To my knowledge at least, no real problems have occurred so far, but I do recognize that is for Bt as a spray. It is true that once we introduce the *Bt* gene into the plant background, the situation may be different. The Commission of the European Community (EC) is currently supporting a project which is looking in detail into the toxicity of Bt produced by plants to human beings. We will have these answers in a very short time.

S. M'Boob (*FAO Regional Office for Africa, Accra, Ghana*). Breeding for resistance by the CG group has largely failed to impart crop protection to the small-scale farmer, for the simple reason that the varieties they produce require very high inputs in terms of fertilizer, water and so on, in order to realize their value. How would these genetically produced varieties compare with traditionally improved varieties in terms of input requirements and cost to the poor farmer?

B. Verachtert. Obviously the germplasm which I have been talking about is being produced by the CG centres themselves, so essentially the inputs required by the resource-poor farmer will be no different from the classical germplasm which he/she has been using so far. The only input, which hopefully would be decreasing, is the input from insecticides.

N. D. Jago (*NRI, Chatham, UK*). As a point of information, there were useful sessions dealing with this topic, and also with the induction of natural resistance within plants to attack by mites and insects, at a recent conference (XII International Plant Protection Congress, Rio de Janeiro, Brazil, August 1991).

On the control of trials of these materials, I think the danger that is envisaged is that these modified genes would get out into wild plants. For example, a very promiscuous plant like *Pennisetum* millet crosses with many wild millets - a resistant gene in millet could outcross to wild grasses which would then become virulent weeds.

B. Verachtert. I fully agree with your comments. Obviously we have to look at these kinds of problems on a case-by-case basis. The EC is also supporting a number of projects looking into the safety assessment of deliberate field releases of transgenic plants; the first results are becoming available and are generally very encouraging - there are very few outgrowths into wild species. Of course the risk is there for transgenic plants, but a similar risk is also present for classical breeding: insect resistance bred into a cultivated crop could also outcross to a related wild species.

I. Haines (*Overseas Development Administration, London, UK*). I have been involved in some of the meetings of the United Nations Environment Programme (UNEP) where the participants are working towards a global convention on biodiversity and biotechnology, and two important issues keep cropping up. One is on the question of safety which has already been raised. I believe there are serious problems here in assuring the public and the farmer that the safety aspects are being adequately addressed, not least because people at the moment seem to be looking for major impacts, while some of the sub-lethal, minor impacts are not being looked for very actively - there is a potential risk there. When Bt first came out many years ago, the label on the bottle said that the product was totally safe, but the small print said "this company accepts no liability for harm to human beings".

The second issue is that of technology transfer. The Convention meetings also showed that the developing countries want access to technology on preferential terms, indeed free access to technology. I wonder what the commercial perspective is on this?

B. Verachtert. From the point of view of a private company, the seed is the carrier of the technology. So for the farmer it is not important whether or not the seed has been produced by a classical breeding programme, by biotechnology, or by any other means. What is of interest to the farmer is high quality seed which will, for instance, produce plants that show insect resistance. If we deal with the CGIAR centres, or with national programmes, in this way we would be able to transfer technology to these specific centres. The centres would gain access to the technology and would be able to use it in whatever way they please, at least within the developing countries.

Your question also deals with direct access to the technology. There are a few practical problems, it is not only a matter of making the technology available, it is also a matter of training the people, having proper laboratories installed and maintained, and making sure that there is continuous exchange between scientists. We do not feel it is incumbent on a private company to organize these things, although over the years we have always had PhD and post-doctoral students from developing countries in our laboratories.

J. Rowley (*OXFAM, Oxford, UK*). I think that the three examples you have given of transgenic plants, potato, tomato and tobacco, are all very closely related. I wonder if you could give the conference a perspective on advances in other plant groups. Will it be some time before we see this kind of work with the grasses, which include a number of the world's most important food crops?

B. Verachtert. I mentioned before that one of the major bottlenecks is the availability of proper transformation systems which enable the introduction of foreign genes into the plant's genome. The system was originally developed for dicot plants such as tobacco, the first plant which was transformed, and was then extended to other dicot plants as well. Monocots have so far been rather recalcitrant to the transformation procedure, but in the last two years there have been a number of reports where transformation has been reported, so that has become possible now. I would anticipate that within the coming year transformation procedures will be available, and also within the coming year monocot plants will be produced which contain the genes for insect resistance, or other resistances, if the molecular work continues to progress at this rate.

F. M. Wambugu (*KARI, Nairobi, Kenya*). Have any transgenic plants actually been released on the open market, or are they still being tested? How long is the testing carried out for?

B. Verachtert. So far there is no transgenic plant material released on the market, although it can be anticipated that within a few years or even next year, especially in the USA, that some of the transgenic plants will be marketed. The first transgenic plant containing a *Bt* gene was produced in 1985. Since then of course there have been tests with tobacco, but I do not consider tobacco as a major commercial opportunity. For other crops, testing will probably take between two to three years and five years.

L.S. Diarra (*SNPV, Bamako, Mali*). One concern for the developing countries is the cost of these varieties. Also, reliance on patented hybrid cultivars will create a situation of complete dependence - in this world of ever-changing political alliances, new world orders and so forth, do you think the developing countries will be taking too great a risk in depending on this technology?

B. Verachtert. The real question is, how can the developing countries best gain access to this technology? We are offering a system through which we feel that access can be gained. This may result in some dependence, but this is the only system we can think of to make the fruits of this technology accessible.

Better cultivars for resource-poor farmers

I. W. BUDDENHAGEN*

Department of Agronomy, University of California, Davis, California CA 95616, USA

ABSTRACT

If the varieties grown by farmers suffer much damage from pests or diseases, better varieties with more resistance would be of benefit, no matter how poor the farmer. However, if the varieties currently grown suffer little damage, then new varieties with greater yield *potential* may not benefit the poor farmer who has no access to fertilizer. In this paper, the interrelationship between the potential value of new varieties and the level of the resource poor in terms of access to different inputs is discussed. If crop varietal resistance levels are sufficiently high, needs for IPM intervention will be minimal. Resistance will be only one of many breeding objectives, so breeding programmes require multidisciplinary teams involving not only pathologists and entomologists but also others who can help appraise the local socio-economic and agroecosystem characteristics. Pathosystem analysis is essential in order to attain durable resistance. Intractable pest problems should be considered opportunities for introducing new crop species. Deploying new varieties is not easy where farmers are already growing improved varieties and the benefit of more resistant varieties may be small. In most developing countries, the private sector has only a small role in plant breeding, but it could be better able to develop the multidisciplinary teams needed to respond to the requirement for better and locality-specific resistant varieties.

RESUME

Si les variétés que cultivent les paysans sont très endommagées par les fléaux ou les maladies, de meilleures variétés plus résistantes seront avantageuses pour le paysan, même s'il est très pauvre. Toutefois, si les variétés cultivées actuellement sont peu endommagées, les nouvelles variétés avec un *potentiel* de rendement plus élevé peuvent ne pas être avantageuses pour le paysan pauvre qui n'a pas accès aux engrais. Dans cette communication, nous examinons la relation qui existe entre la valeur potentielle des variétés nouvelles et le niveau d'accès aux différents intrants qu'ont les paysans disposant de peu de ressources. Si les niveaux de résistance variétale des cultures sont suffisamment élevés, la nécessité d'une intervention d'IPM sera minime. La résistance ne sera qu'un des nombreux objectifs de la sélection et c'est la raison pour laquelle les programmes de sélection doivent avoir des équipes pluridisciplinaires, comprenant non seulement des pathologistes et des entomologistes mais aussi d'autres chercheurs qui puissent évaluer les caractéristiques socio-économiques locales ainsi que les caractéristiques de l'agro-écosystème. Une analyse de l'interaction qui existe entre le pathogène et ses hôtes est essentielle pour obtenir une résistance durable. Il faudra considérer les problèmes de fléaux insurmontables comme une chance d'introduire de nouvelles espèces de cultures. Il n'est pas aisé de déployer de nouvelles variétés lorsque les paysans sont déjà en train de cultiver des variétés améliorées et que l'avantage des variétés plus résistantes est peut-être faible. Dans la plupart des pays en développement, le secteur privé ne joue qu'un petit rôle dans la sélection végétale mais il pourrait être mieux à même de développer les équipes pluridisciplinaires nécessaires pour répondre au besoin en variétés résistantes améliorées, spécifiques à un endroit donné.

INTRODUCTION

I was originally given the title "Resistant cultivars for resource-poor farmers": as 'resistance' is just one of many criteria plant breeders use in developing new cultivars, I have broadened the title to encompass the holistic process and purpose of developing 'better' varieties.

The first question to ask is whether the resource-poor farmer requires varieties different from those of the resource-rich farmer. If yes, then does this mean special breeding projects or programmes? Who is to pay for and man such programmes? If no, then one may ask if the resource-poor farmer is well served by existing breeding programmes whose targeted output is 'better varieties' *per se*.

I have argued that "greater efforts to develop more resistance that is more durable would be in the public interest" (Buddenhagen, 1983e). Also that "the local agroecosystem...must become the focus of research if change is to occur which is balanced and beneficial" (Buddenhagen, 1976). The arguments still stand.

*Professor Buddenhagen was unfortunately unable to attend the seminar; this paper was presented by Dr R.W. Gibson.

The target should be a local agroecosystem, in which there may be farmers ranging in resources from poor to rich and who either have or do not have crops or varieties ideal for their agroecosystem. And I emphasize that the varieties farmers grow are the fundament for pest/pathogen populations - they are their food source. These may be either inhibitory to, or conducive of, pathogen/pest population growth or pathogen/pest evolution. Thus, the plant breeder and others involved in varietal development determine: (i) disease/pest depredation potentials, (ii) pesticide needs, (iii) biocontrol and other IPM needs, (iv) productivity/stability levels, and (v) profitability potential.

RESOURCE-POOR FARMERS

Clear definitions of terms can clarify thinking and communication, especially where issues and personal bias prevail. The term 'resource-poor farmer' could cover farmers in many different situations. Moreover, resource-poor farmers can become less resource-poor if they can become more productive by whatever means - including the cultivation of a 'better' variety. For my purpose I will classify resource-poor farmers into three groups: I, no access to external manufactured fertilizers or pesticides; II, limited access to external fertilizer only; III, limited access to external fertilizer and pesticides. No or limited access could be due to either no or limited money or credit, or to absence or limited availability of supply. (Increasing access for these two situations would have different solutions.) Beyond these resource-poor farmers are 'resource-rich' farmers who have ample access to external fertilizer and pesticides. But these farmers, to survive and prosper, must keep inputs as low as possible in relation to output. Thus their crop varietal needs really do not differ that much from the other groups. A variety sufficiently resistant to a pest or pathogen is useful to all. A variety better able to produce a saleable product at low fertilizer input level is useful to all. However, so far as resource-poor farmers of groups I and II are concerned, sufficient and durable resistance to local pests and pathogens is essential, whereas resource-rich farmers, given appropriate knowledge, equipment and pesticides, may not be devastated by lower levels of resistance or by resistance breakdowns.

THE FACTORS OF PRODUCTIVITY

It is useful to clarify the key factors of plant production, which are light, air ($CO_2 + O_2$), water, temperature, nutrients (in soil), and the plant genotype itself. In a natural ecosystem the biota is complex and to a large extent life continues with recycling of the nutrients from one to another, with minimal loss from the local area. Productivity is limited by the key factors interacting on the nutrient base, and by the degree to which these nutrients are sequestered in macromolecules in living or dead tissue or in inorganic soil complexes.

The product removed from the field (usable yield) contains elements (nitrogen, phosphorus, potassium, calcium, zinc, etc.) that came from the soil and must be replaced for continued production. Increased yield means increased nutrient removal. Thus, our very success in developing higher-yielding varieties triggers the need for greater additions of elements to replace their greater removal. This means that group I farmers can benefit little from higher yielding varieties, at least not for long.

Plant breeders can manipulate the crop genotype only slightly in relation to these major static productivity factors. The key innovation generating the 'green revolution' was the dwarfing of rice and wheat, enabling more nitrogen to be added to the system without lodging of the crop. Low nitrogen remains the key limiting production factor for non-legume crops of resource-poor farmers. Other nutrients are also often limiting. For a few crops, breeders have altered crop duration or canopy characteristics to utilize better the seasonal rainfall, temperature or light. The scope here is, however, only marginal. For a few legumes, breeders have bred varieties that can fix more nitrogen than previous varieties, or have enabled them to fix nitrogen with local rhizobia with which they were previously incompatible.

THE DEPREDATION OF POTENTIAL PRODUCTIVITY

Pests and pathogens of crops decrease harvests and product quality as well as causing enormous post-harvest losses. Total estimates vary greatly but averages tell little about the devastation to lives and families of the resource-poor whose crop is eaten or blighted, or whose food store is riddled with insects. Malnutrition and even starvation may follow. Therefore, it behoves the plant breeder, pathologist and entomologist to take very seriously the need for sufficient resistance that is also durable, as they attempt to develop and then promote new varieties of crops.

It is important that the plant breeder knows the existing and potential pest/pathogen problems in the target area for a new variety. Often he/she does not know enough because the target area is too large, the travel budget and time for observation too small, and acquaintance with pests and pathogens too superficial. Ideally, there is a multidisciplinary crop improvement team with good internal rapport, proceeding together to understand the target area, the target farmers and the existing and lurking pests and pathogens. Ideally this team would spend enough time talking with farmers and observing their lives and environment to make good judgements on what is useful to do.

All too seldom does such a team approach to crop improvement exist. University education in separate departments of Entomology, Plant Pathology, Horticulture, etc. tends not to foster teamwork centred on breeding for farmer-needed goals of better varieties having higher levels of more durable resistance. Although resistance also benefits farmers in advanced countries, where most agricultural scientists are trained, its paramount importance is less emphasized due to the numerous options for pest/pathogen control available in a higher technology system.

Nevertheless, resistance targets of breeding are important for all crop improvement programmes and they should be the major emphasis where resource-poor farmers are to be the recipients of new varieties. A small improvement in resistance levels can mean much less pest/pathogen depredation and much greater effectiveness of applied control measures. But exactly what resistances are needed and how does one go about achieving this goal?

AGROECOSYSTEM ANALYSIS

Every region or local area where agriculture is practised has its own characteristics - of climate, soil, crops, natural vegetation, pests and pathogens. The multiplicity of interacting factors condition different possibilities for economic productive agriculture and for different crops. Grafted onto the natural ecosystem is the cultural and socio-economic background of the human inhabitants, and their past and present effects on the ecosystem. They may already have overused and degraded the ecosystem so as to make varietal improvement largely irrelevant; if not, sufficient knowledge may provide options for positive change.

In any event a 'quick and dirty' overview by an experienced, widely travelled agriculturalist will reveal whether the farmers are deficient in terms of the kinds of crops they are growing in their ecosystem. This judgement should be made before looking closely at the cultivars being grown and judging whether they are sufficiently deficient in resistance or other characteristics to merit either new cultivar introductions from a foreign breeding programme, or intensification or initiation of a local breeding programme. This latter analysis will require input from local people and repeated field visits during the growing season, and visits to post-harvest stores to ascertain pest/pathogen problems and the level of losses. Usually, much local knowledge exists alongside written material. Judgement is required, however, by a person knowledgeable of the crop, its performance elsewhere, its pests and pathogens, variety diversity and existing breeding programmes and targets.

In poor areas the major limiting factor to productivity, especially in Africa, will be nutrients: nitrogen for non-legumes and phosphorus for all crops, but also potassium, calcium, sulphur, zinc, etc. Also, for rainfed crops periodic drought will often be limiting, especially on sandy soils of low waterholding capacity. Although it is often stated that the need is for varieties that are drought resistant or that will do well on poor soils (where resource-poor farmers largely are), expectations here should not be great. Moreover, just how much better varieties with more pest/pathogen resistance will perform under such situations may well be over-rated.

PATHOSYSTEM ANALYSIS

Although pathosystems are an inherent part of the agroecosystem, they are singled out here for emphasis. There are several key points which should be appreciated equally by those concerned with breeding varieties, with biocontrol or with IPM.

(i) Pathosystems have their evolutionary roots before man; they have evolved with crop domestication and with crop intensification (Buddenhagen, 1977).

(ii) Pathosystems were geographically circumscribed due to co-evolutionary factors or accidents; however their ranges (and host ranges) may change as either pest/pathogen or hosts are moved purposefully or accidentally to new regions. Many of our great epidemics resulted from this process (the Irish potato famine is the most famous historical consequence).

(iii) Pest/pathogen epidemics due to new encounters or re-encounters are the most amenable to either biocontrol and/or breeding solutions. Classical examples here are the cassava mealybug and the *Puccinia polysora* maize rust epidemics in Africa - both were re-encounters of co-evolved American pathosystems centuries after the crops themselves had spread across Africa.

(iv) Pest/pathogen severity is ecologically circumscribed. Susceptible varieties may be severely, moderately, slightly or hardly damaged even in an area containing the pest/pathogen, due to weather conditions (usually rainfall or humidity) or seasonal conditions which either favour or inhibit the disease or pest depredation or the pest/pathogen life cycle. Thus, how much resistance is needed will vary ecologically. Breeders may be correct to concentrate on other varietal characteristics if their variety is targeted for an area not conducive to a particular disease. However, a variety's success in one location may easily result in attempts at commercializing it in other areas where a pest/pathogen is favoured, resulting in major losses. (Examples here are many, where high-yielding varieties of rice or wheat were moved from Asia or America into Africa, where they were too susceptible to blast or other leaf pathogens. Also, maize bred in the west African savanna can be severely affected by leaf diseases in the conducive, wetter forest zone to the south.)

(v) Pest/pathogen severities are culturally/technologically influenced. Two key factors of the dwarf high-yielding varieties were a changed height and canopy density, along with a raised nitrogen content. This changed the pest/pathogen potential even without a change in resistance *per se*. For rice, planthoppers and leafhoppers and their vectored pathogens became much more severe and important. Bacterial leaf blight of rice was long present but unrecognized in tropical Asia until the advent of high nitrogen use with the high-yielding varieties. Thus, as agronomic attempts are made to increase yields, lengthen the growing cycle, institute no-tillage or double cropping, etc., the importance of the pathosystems will change. Different levels of varietal resistance or other means of pest/pathogen regulation will be needed. This should be expected, but it often is not, and 'technology' receives inordinate blame.

(vi) The idea that local landraces as a group have high levels of pest/pathogen resistance is considerably over-rated. Furthermore, that ancient or present resource-poor farming was or is blessed with a pre-Pandora absence of important pest/pathogen problems is just not true. The Roman rust god Robigus, and the many allusions in the Bible to famines and pestilence, attest to the ancient and continuing struggle between man and his biological environment.

Where pathosystems are anciently evolved *in situ*, many pests and pathogens may keep productivity low and farmers poor. For cowpeas in West Africa, insects cause considerable loss which is, to some unknown extent, kept down by local practices of wide spacing, mixed cropping, varietal variability, and extended flowering period of some landraces. How much these farming practices actually reduce damage is hardly investigated, but it is probable that crop intensification *per se*, within and between fields, would result in increased damage of existing landraces. It is highly likely that such practices giving reduced damage over time enable landrace lines to harbour higher levels of susceptibility than would be the case for modern varieties grown under higher technology levels!

(vii) To balance the previous point, it should be mentioned that in co-evolved systems where the ecological conditions highly favour a pest/pathogen of a particular crop, it should be possible to find useful levels of resistance. Germplasm collection of crop plants and their relatives should be intensified in such specific locations, where the pests/pathogens should also be collected. Plants having low levels of damage there may well have high levels of resistance that may be horizontal (durable). A good example is blast disease of rice. It has long been known that blast is much more severe when normal flooded rice is exposed to non-flooded, free-draining conditions. Testing for blast resistance evolved decades ago into an 'upland nursery bed test'. However, rice breeders (or pathologists) did not extend this concept to examining and using, as resistance parents, landrace rice varietal types that had been grown by farmers in Africa and Asia for centuries under upland conditions in ecological situations highly conducive to blast, where they remained little diseased. The use of this resistance source has occurred only recently, first in Africa, from where the idea and germplasm were taken to the Centro Internacional de Agricultura Tropical (CIAT) in Colombia, and now to the International Rice Research Institute (IRRI) in Asia.

MISSING CROPS

New varieties with more resistance that are also better generally are the target of most breeding programmes in developing countries. Since most money, public resources and relevant publications are concerned with the major food crops covered by the international agricultural research centres (IARCs) and are also covered by many national agricultural research stations, we also are somewhat biased by this emphasis. Less than 20 crops, with only about ten really covered in moderate depth! Yet the Food and Agriculture Organization of the United Nations (FAO), as an intergovernmental agency trying to assist many struggling agricultural areas, handles projects or some activity in-country on some 200 crops. Italy or California alone have over 150 crops each. What is the potential for expanding the crop species diversity of the resource-poor farmer, at least for local or family use?

Despite all the post-Columbus interchange of crops, one still finds the three tropical worlds quite different in terms of crop germplasm available to the local resource-poor villagers. This is especially true for the fruits, nuts and vegetables that might be produced locally with minimal effort. Africa especially is deficient in the diversity of tropical fruits present in Asia. Many useful fruits popular in Brazil are little known elsewhere. Vegetable soybeans, rich in protein and fat, which could be grown easily in compound gardens, are almost missing from Africa. The list could go on and on, but the key point is that the resource-poor are often nutritionally poor, and in addition to a new 'more resistant' rice or maize variety for their fields, there is also much that could be done by distributing adapted germplasm of 'missing crops' intercontinentally, and beyond the confines of experiment stations. It is in the villages - which often need shade - where organic matter is plentiful and nutrient-laden, where a great diversity of missing crops could be grown successfully on a small scale, and could make an important contribution to the lives of the resource-poor.

Vegetables, especially, are terribly neglected, poorly distributed and often missing from places where they would grow well. They have many important disease and insect problems, and they receive great quantities of pesticides. In any given ecosystem, are the best species being grown or even looked at? For vegetables one should start with genera and species questions before going after the equally important cultivar adaptation and resistance questions. For instance, in the wetter tropics where cowpeas do poorly and are susceptible to many pests and pathogens, could lima beans (*Phaseolus lunatus*) or soybeans serve?

The idea that people will not take to new crops just does not fit the facts. The average Nigerian villager cannot imagine life without cassava, maize, rice, tomatoes, chillies, tobacco, groundnuts, onions - all 'new' crops. Other 'new' crops in the African tropics are sweet potatoes, potatoes, eggplant, coco-yams, cucumbers, common bean, bananas and plantains and even avocado, mango and papaya. People will take to new crops, but only if they are distributed. Maybe some new village crops would be a better investment than intractable resistance breeding of an existing crop. The problem of course is that if you are hired to do cowpea breeding you do not think of substituting a different crop. Research management and donor inadequacies are at the heart of this dilemma.

INADEQUATE RESISTANCE

The very existence of this conference is proof of the inadequacy of resistance in our crops. Some crops, left unprotected, are damaged much less than others. Also, crop products vary greatly in this respect.

Given all the effort at developing varieties labelled 'resistant' to various pests and pathogens, why is resistance often still so inadequate? I have addressed this question in various papers, hoping to influence crop breeding programmes to be more concerned about this issue (Buddenhagen 1977-1983). I have also developed or reviewed international projects targeted at better, more resistant varieties of various crops. And I have done 'hands-on' breeding and selection, or led crop improvement teams, that actually developed better varieties of various crops with better resistance. These varieties are being grown widely by farmers, many of whom are resource-poor.

From each of these experiences I have learned something, and have come to some key conclusions.

(i) Much more can be accomplished towards resistance, and most breeding programmes can benefit from more stimulus, more innovation and more teamwork.

(ii) Every crop and pathosystem is different, and some are much harder to 'crack' than others, no matter what the input level.

(iii) Much good material that might benefit the small-scale resource-poor farmer sits on experiment stations or in repetitive test plots, unavailable to farmers, or delayed overlong in reaching them.

(iv) The PhD training of plant breeders, pathologists, entomologists, etc. is either neutral or opposed to the across-discipline approach to problem identification and solution. Therefore in public organizations, even in developing countries, the very formation of 'crop-improvement teams' is difficult and has little scientific or administrative support.

(v) Balancing the diverse interests of breeders, pathologists, entomologists and others who make up a crop-improvement team, in their quest for professional within-discipline status, with the needs of farmers and crops is a difficult management exercise. It is often made more difficult by the present trend at a higher organizational level to divert resources to studying farming systems, to studying 'sustainability', to *post-mortem* social and economic studies, etc.

(vi) Plant breeding in the private sector approaches most closely an across-discipline team effort, and therefore private sector programmes should be fostered in developing countries.

(vii) Intractable resistance problems should be reviewed carefully for the possibility of a biotechnological approach to their solution. Such attempts should be part of a regular crop improvement effort, and should be backed up with studies on resistance breakdown and resistance management (Gould, 1990). As the financial resources needed are considerable, they should be concentrated in only a few programmes for each major problem.

(viii) Efforts towards horizontal resistance goals and towards developing appropriate methodologies of selection for horizontal resistance need much greater emphasis (Simmonds, 1991).

(ix) Testing of new varietal types possibly useful to the resource-poor farmers needs to be changed. It should be done under resource-poor conditions with farmer involvement. The farmers should be enabled to use what they want, with as little involvement as possible of the bureaucratic and slow process of the western concepts of seed purity, seed certification and seed release rules.

(x) Efforts to develop varieties of the basic food crops that will do better on local soils with their specific nutrient and water limitations need to be intensified, with innovative concepts and methodologies. Satisfying realistic resistance needs should accompany such efforts.

REACHING RESOURCE-POOR FARMERS

If you work for a small salary in public sector agriculture in a developing country, and have no or minimal operating funds, it will be difficult for your efforts to benefit the resource-poor farmer. If your rewards do not change whether or not you benefit him or her, it will be even more difficult. Thus, one must respect and commend the international and philanthropic agencies that have attempted to stimulate change in many different ways, with outside funding. Even here, however, funds are limited and the problems remain enormous. One needs to focus on catalysts - products or activities that have inherent multiplier effects. Self-generating incentives will work, and the best incentive is profit.

If a resource-poor farmer is convinced that by planting a new variety he has a good chance of making more money he will do it - even if he has to pay for the seed. But a new variety alone usually will not do this unless his old variety has some major susceptibility problem that is rectified by the new variety. Hence the importance of concentrating breeding on rectifying existing local susceptibility problems. And hence this exposition's starting point with agroecosystem and pathosystem analysis.

I have argued that except for these limited areas where present susceptibility is a major problem, "crop breeding is best viewed for the third world as a catalyst of change" (Buddenhagen, 1986). This means a catalyst of input changes as well as of output. Otherwise there will be little increase in productivity and thus little adoption, regardless of the outside push.

There are many ways to reach the small farmer and all involve communication. All take money and effort and presumably the mechanisms will be reviewed in depth at this conference. I am concerned specifically with what the farmer is reached with, in relation to better or different crop germplasm, that also reduces pest/ pathogen depredation. And with comparisons with other mechanisms to reduce pest/pathogen losses.

(i) The cleanest and simplest innovation to reduce pest losses is the exploitation of a biocontrol mechanism that actually works. An internationally funded operation that backs development and dispersal of a biocontrol agent that works essentially bypasses all the human and organizational blocks to success. The cassava mealybug in Africa is the classic example (see page 45). In-house work led to parasite discovery, propagation and release. Release was from an airplane over wide geographical areas, or from vehicles along roads. The multiplier effect was self-generated by the high pest populations. Subsequent spread was natural and the pest became much less important. The only human hurdle to be overcome was to gain permission for release.

    The only problem (and it is a major one) is that of generalizing that this success will be a general phenomenon. It won't. Biocontrol works well only in certain pathosystems, and the central key is to apply it to either re-encounter or new-encounter field pest problems. For pathogens it will not be so easy even for the re-encounters and for these, as well as for storage pests, many human infrastructural problems will become hurdles to successful application.

(ii) The next cleanest and simplest innovation is where a major susceptibility exists (as above) due to a new encounter or re-encounter, and more resistant germplasm can be brought in or bred quickly. This will work best for pathogens but also for some insect pests. A new variety is released and disseminated, and results are so marked that farmers become their own multiplier effects. Maize streak virus resistance and *Puccinia polysora* maize rust in Africa are classical examples.

    However, before the new variety gets to the farmer there will be many hurdles involving scientists' self-interest, quarantine, local testing, adaptation inadequacies, seed service inadequacies, certification requirements, extension service linkage, extension service limitations and general infrastructural and bureaucratic problems of many kinds. If the innovation is useful across 20-plus countries, and people in all of the above organizations need to be involved - and especially if there are local breeders who want only their own new varieties to be used - one gets an idea of the logistical problems the resource-poor farmer faces.

(iii) The next cleanest biological innovation will be where a disease that is not a re-encounter or new encounter exists that is severe locally, and where resistance is known and can be brought in and used directly or used in breeding. Some pests may fit here as well, but screening for pest resistance to enable separation of genotypic from environmental or phenotypic effects is usually more difficult, takes more money and more expensive staffing. (The paragraph above also applies.) For both innovations (ii) and (iii) above, there should be ready acceptance by resource-poor farmer groups I, II and III. In fact group II farmers (some fertilizer used) and group III (also some pesticides) may accept better resistance more readily because they will see it as either reducing inputs or making the inputs pay off better: i.e. more profit on investment.

Another clean biological innovation can work for points (ii) and (iii) above, for clonal crops, where the existing disease is important, systemic, and only slowly transmitted through mechanisms other than planting stock. In such cases, through meristem culture or other means, clean planting stock can be developed, propagated and disseminated. This will work for many diseases, such as for cassava mosaic in East Africa. It has potential, combined with eradication campaigns, to enable restocking of local areas with 'clean', healthier and more productive plants. Many of the logistic and human problems will still exist. But on a local basis, by involving local villagers in their own welfare, progress here could be rapid. I have proposed the rejuvenation of the Tonga banana industry with this approach to eradicating banana bunchy top virus (so far, no takers).

(v) Next comes varietal change where pest/pathogen problems are usually minor. To make a real difference a farmer must do more than just use seed of a new variety - he/she must obtain and add fertilizer. This would be where existing varieties combined with existing technology do fairly well with their pathosystems. For resource-poor farmer groups II and III, already on the 'improved' variety path, a new variety will have to clearly yield more (or fit some other perceived need) with the same input level or yield the same with fewer inputs. For farmers of group I it will mean getting onto the purchased input path - probably a good move in good environments and probably questionable in others.

Most IARC breeding programmes and many of those of national agricultural research stations are on the horns of this dilemma: their clientele farmers are already growing 'new' varieties. Any further 'new' variety has either to do something very special or increase the existing input/output ratio. This is hard to do unless inputs involve pesticides. If they do, then this means a pest/pathogen resistance target is needed as discussed in points (ii) - (iv). If inputs only involve fertilizer, it means going after fertilizer-use efficiency as a breeding target. This is hard to do. Some progress is possible for some situations but it will take more science, and involvement of plant nutritionists and soil scientists with breeders - traditionally not done. Also, there are inherent problems of mining the soil for scarce nutrients, as well as many local genotype-environment differences. The other potential client is resource-poor farmer I, where the intent is to convert him to a group II farmer (new variety plus some fertilizer). With water non-limiting, this probably is a good idea. But I suspect that the largest proportion of group I farmers are in environments where periodic water limitations make genotype-environment interactions so great as to risk investment in fertilizer.

So we have major dilemmas in trying to generalize about 'better' varieties. It comes down to the point that where 'new' varieties are already in use, further improvement that is meaningful will have to follow much greater knowledge of the local situation, the local perturbations in pathosystems, the limitations of the local environment, and much understanding of the recent local trends in farming itself. Beyond all this is the shifty nature of the genotype-environment-pathogen interactions with time itself.

What seems real is that new technology in the form of new varieties has been a major pump driving the changes of resource-poor farmer group I -> group II -> group III -> resource-rich farmer. It would be better if plant breeding teams could help the system evolve without the group III stage (pesticides).

Before giving too much credit to breeding we should note that for quite a few tropical crops farmers still grow ancient varieties, and yet they too have gone through the above evolutionary changes - with the improved technology pump of fertilizer, water control, mechanization and pesticides. Bananas are the perfect example.

(vi) IPM (integrated pest management) is an acronym for a research and application activity targeted at reducing both pesticide use and pest/pathogen damage. It is a good activity. Where pesticide use is high or irrational (as was the case for insects on high-yielding rice varieties in tropical Asia), its development was needed and has been very successful. But we should not forget that IPM's genesis was due to a combination of excessive use of insecticides and the evolution of insecticide-resistant insects. And that excessive use of insecticides had its roots in varietal susceptibility to insects, i.e. the process of varietal development wherein either insect resistance was neglected or insect evolution ignored, or both. Thus IPM is needed largely because of poor plant breeding (or no plant breeding) combined with intensification of production, especially fertilizer use.

I endorse IPM as a useful way of thinking about agricultural pathosystems and of influencing them to man's advantage. I wish to stress however that where IPM is most needed is also where resistance breeding is most needed. Investment and effort for both activities should proceed in concert. As resistance breeding becomes more successful, the need for IPM field activities should lessen. I have been concerned that IPM practitioners often seem not to appreciate that crop varietal resistance levels determine - are the fundament for - both the levels of pesticides needed and the need for IPM. I have naively thought that the IPM group and their donors should support or at least endorse efforts to develop varieties having more resistance. At least in California, that does not occur and research proposals for breeding for resistance receive no support from that group.

In Africa, for most crops, pesticide usage is very low. Thus the target of classical IPM (reduce sprays through pest monitoring and threshold measurements) is largely not present (there are exceptions, e.g. cotton). However, the idea of a better understanding of pest biology could be very useful to both the plant breeder and those interested in biocontrol interventions. Thus we return to a need for better local agroecosystem and pathosystem analysis.

Regarding IPM interventions where needed, they involve the heaviest participation of extensionists, farmers and researchers, and the most organization and communication. FAO has been very successful on rice IPM in Asia on a large scale. In tropical Africa, where there are many more organizational and infrastructural hurdles, and less need, investments would be better placed in research activities that will preclude the over-use of pesticides, i.e. resistance breeding and biocontrol.

A final point on the private sector

(vii) Most of the previous discussion relates to work in the public sector. In most developing countries the private sector in agriculture has not developed a very balanced or a very important role. This is unfortunate, as the private sector has much to offer and it certainly has played a major role in the evolution of the highly productive, efficient agriculture of developed countries. One may wish to believe that there is something fundamentally different about tropical needs or the colonial past of many tropical countries that should inhibit the development of a large private sector in agriculture. However, one has only to look at Eastern Europe or Russia to see how, in the temperate zone also, the absence of balanced growth of a private sector combined with the dominance of centrally controlled public activities in agriculture has been negative.

In tropical developing countries, basic production is private but the evolution of agro-industries, agricultural research and service in the private sector has been stunted - especially in Africa, but even elsewhere. The local élite do not see agriculture or its services as good investments. The outside international organizations have tended to deal with the federal governments - the ministries. The public sector grows. The private sector withers or develops excesses of get-rich-quick schemes. The development of local seed companies has hardly occurred in black Africa. Local fertilizer production has also been stunted. The same for pesticides and other inputs. Where are the private plant breeding programmes in the tropics? There are a few, but not many. Who is breeding vegetables for the tropics? Japan, Netherlands, New Zealand and the USA. But are they doing good tropical breeding or just selling seeds? (The Asian Vegetable Research and Development Center, AVRDC, in Taiwan does public sector, internationally funded vegetable breeding.)

I am making the case that with greater emphasis now on local problems and possibilities in the tropics, there is a need to stimulate private entrepreneurship in agricultural research and agribusiness in developing countries. Pertinent to this topic is the need to develop local seed companies, and these should do crop breeding as well as quality seed production. If it takes hybrids to finance their development and continuation, so be it. They can branch out later to quality seed production and the development of inbred crops. The private seed sector could be a great boon to agricultural development in the tropics.

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DISCUSSION

W. N. O. Hammond (*IITA Biological Control Centre for Africa, Cotonou, Benin*). This paper describes IPM as being different from resistance and biological control. I think we are talking about components of IPM, but to avoid confusion, perhaps we need to avoid using the term IPM and find another word - what we are really dealing with is system management as a whole.

J. Farrington (*IIBC, Silwood Park, Ascot, UK*). On the issue of the private sector, I would very much like to share the speaker's optimism that private sector seed producers could benefit African farmers. In looking for countries where private seeds industries have been successful in serving small farmers, I think we have to look outside the ACP countries, maybe at Latin America, the Philippines, Thailand or Malaysia. In these countries there has been some success in dealing with resource-rich farmers, and maybe even Dr Buddenhagen's group III, but certainly not with his group II or group I farmers. The markets for these small-scale farmers are very small, they may be difficult to gain physical access to, and so they are not profitable markets for private seed companies to go into.

J. C. Reid (*CARDI, Kingston, Jamaica*). I think that we are in danger of over-simplifying the definition of 'resource-poor'. The limitations are not only of the lack of fertilizers or pesticides, but of labour, water and equipment. We should avoid the misconception that we can solve farmers' problems by just making the two elements, fertilizers and pesticides, available. Perhaps many of our considerations should be system based, not only systems where the farmer is dealing with a multitude of commodities, but community system-based operations.

S. M'Boob (*FAO Regional Office for Africa, Accra, Ghana*). I become worried by resistant cultivars for resource-poor farmers, because there is no system established. Twenty years ago, it was widely believed that we were going to breed out pests and diseases for resource-poor farmers. But after all this time we have not succeeded in doing this - in fact, pest problems for resource-poor farmers have increased and intensified. There are various reasons for this, but I think the basic issue is that new varieties do not seem to be the solution to the problem (although they might be part of the solution). The reasons range from the high cost of varieties, the breakdown of resistance, and in dealing with difficult areas like the Sahel, new pests are found - 20 years ago we did not have *Heliocheilus*, or the millet borer problem. I think when we deal with resistant varieties for resource-poor farmers we have to be very careful as to how they are placed within the context of IPM.

We refer very often to the success of the IPM story in Asia. But that success is not based on resistant varieties, it is based on exploitation of inherent traditional factors within the agricultural system - we have failed to do this in dealing with resource-poor farmers in Africa, where the approach has always been IPM based on very high technology. We might be offering a beautiful 'basket of choices', but in the end these choices will never be implemented because (i) the resources are not there to be implemented, and (ii) if they are implemented, the elements are not sustainable and some will break down. We need to redefine the whole process by starting with the farmers' traditional values.

I. W. Buddenhagen, who was not present at the seminar, has contributed the following comments.

Breeding programmes are not funded by those who fund IPM, and research on IPM is nearly always unrelated to research to attain resistance. Ideally one could have resistance as part of IPM, but I think IPM donors and constituents do not operate that way, either in thinking or in research approaches.

If new varieties really are developed by the private sector and they do succeed with the better-off resource poor, they will spill over to the less well-off farmers, either through national or state seed services or through farmer exchange. The seed companies may not make much money from the poor farmer, but he can benefit. The key is whether a new variety is more *farmer* profitable. With class I it may well not be; for class II it should be, and if not it is bad plant breeding.

Farmers do face limitations other than fertilizers. The first step, however, has to be to increase profitability, and this nearly always will be through increased production, which will nearly always start with adding fertilizer. If one makes more money, one can begin to pay for other improvements - labour, water, equipment, etc.

I doubt that there was ever a possibility of our breeding out pests and diseases, and would question that pest problems have increased generally for the resource-poor. Maybe awareness of pests by bureaucrats has increased. New pests (re-encounter pests) have been involved, and of course these make new problems. But certainly the old diseases of maize streak and cassava mosaic are much less damaging on varieties bred for resistance to these problems. I do not think the 'high cost of varieties' or 'the breakdown of resistance' are the problems.

In Asia, the IPM efforts and successes were based on backing off from excessive pesticide use through proper local monitoring of pest levels and establishing thresholds. The lesson seems clear: don't start in Africa along the route of excessive pesticide use.

Crop protection in small-island systems

U. W. MARTIN

Inter-American Institute for Co-operation in Agriculture, Botanical Gardens, Roseau, Dominica

ABSTRACT

Farmers in the small islands of the Windward Islands can be considered to be resource-poor because of the constraints of land, labour, capital and managerial ability under which they operate. Agriculture is centred on the growing of fruit crops for export, and this places farmers under the additional pressure of having to use expensive crop protection measures in order to meet the standards demanded on the export market. Crop protection faces a dilemma: the present methods are inappropriate but there are few alternatives. A way forward is suggested which involves technology generation, networking, training, nursery management, and agro-processing.

RESUME

Dans les petites Iles du Vent, les paysans peuvent être considérés comme disposant de peu de ressources à cause des contraintes en matière de terres, de main d'oeuvre, de capital et de capacité de gestion qu'ils connaissent. L'agriculture est axée sur la culture de fruits pour l'exportation et ce fait exerce une pression supplémentaire sur les paysans qui doivent utiliser des mesures onéreuses de protection des cultures afin d'atteindre les normes exigées sur le marché de l'exportation. La protection des cultures connait un dilemme: les méthodes actuelles sont inappropriées mais il existe peu d'alternatives. Un progrès est suggéré et il comprend l'élaboration d'une technologie, la mise sur pied d'un réseau, la formation, la gestion des pépinières et le traitement des produits agricoles.

INTRODUCTION

The Windward Islands are situated in the eastern Caribbean between latitudes 12 and 16°N. They are, from north to south, Dominica, St Lucia, St Vincent and the Grenadines, and Grenada. The Islands are volcanic in origin, with a central range of mountains from which offset spurs run to the coast. The climate is tropical with a wet season (May to December) and a dry season (January to April). Average annual rainfall ranges from 1750-3590 mm. The soils are mostly heavy clay loam with a low organic matter content. The Islands are relatively small, with a total area of 172 046 ha (Table 1).

The economies of the Islands are classified as 'under-developed' or 'developing' and the sub-region experiences most of the major economic problems common to such economies. The Islands rely to a large extent on export earnings and foreign investment for income generation. Their economies have trouble competing on the international markets and exportable items are subject to wide price fluctuations. Changes in prices of exports contribute to serious balance of payment pressures (La Gra & Marte, 1988). These problems are derived partly from the specialized nature of the economies. The sub-region is dependent mainly on agriculture which provides an important source of income, export earnings and employment. Its contribution to the gross national product (GNP) ranged from 16% (St Lucia) to 30% (Dominica) in 1984 (Table 2). Since colonial times, the agricultural sector has been dominated by a few crops, leading practically to monoculture. The principal crops are export-

Table 1 The Windward Islands

Country	Area km^2 (m^2)		Population (year)	
Dominica	750	(289.5)	81 200	(1988)
St Lucia	616	(238)	128 000	(1985)
St Vincent & the Grenadines	389	(150)	134 000	(1984)
Grenada	344	(133)	113 000	(1988)

Table 2 Percentage contribution of agricultural production to gross national product

Category	1985	1986	1987	1985	1986	1987
	Dominica			Grenada		
Agriculture	27.9	30.3	29.9	17.9	18.2	18.8
Manufacturing	6.4	6.7	6.6	5.0	4.8	5.4
Construction	6.7	4.7	5.3	7.9	13.3	9.4
Hotel and restaurant	1.2	1.2	1.3	6.2	6.7	6.3
Government services	22.5	21.5	20.7	20.9	20.3	18.3
Other sectors	35.3	35.8	36.2	42.0	36.7	41.3
	St Lucia			St Vincent		
Agriculture	15.0	16.6	14.4	19.8	19.4	20.8
Manufacturing	8.5	8.0	7.9	11.5	9.5	13.4
Construction	6.9	7.5	8.1	7.8	11.2	8.3
Hotel and restaurant	6.8	6.8	7.2	2.0	2.0	2.0
Government services	21.6	21.6	22.1	17.2	16.5	10.5
Other sectors	41.2	39.6	40.4	41.8	41.3	42.8

Source: OECS Statistical Pocket Digest 1987 - OECS Economic Affairs Secretariat

oriented and marketed to only a few foreign countries. The Windward Islands import a wide range of materials, including food for domestic needs (e.g. sugar, rice, meat, dairy products, cereals).

In their development strategy, the governments have placed much importance on agricultural development. Efforts are towards import substitution, increased agricultural exports, increasing incomes within the sector, and improving the nutrition of the population. The governments are now reversing their previous neglect of non-traditional crops through crop diversification programmes (Brathwaite *et al.*, 1983). Among the crops identified as non-traditional by the various ministries of agriculture are avocado, mango, passion fruit, pawpaw, aroids, breadfruit, ornamentals, sweet potato and citrus (Ministry of Agriculture, Dominica, 1989). Traditionally the Islands have been exporters of agricultural products, e.g. bananas, sugar, cocoa, etc. It is essential for successful marketing of such products not only that they be of the highest quality, but that they are free from pests and diseases.

Many of the current crop pests and diseases in the Caribbean are introductions, and the Islands are constantly exposed to the danger of introducing pests and diseases from nearby countries. These include the Mediterranean fruit fly in Central and South America and California, the golden nematode from Panama and Peru, and coffee rust from Brazil and Central America (Bennett *et al.*, 1974; Brathwaite, 1983; Small, 1983; Schotman, 1989).

I will now move on to the constraints which contribute to the farmers of these small islands being resource-poor. Then I will attempt to identify the major problem facing crop protection in the Islands, and propose a possible solution. Firstly, however, some background is needed to the following discussion.

* There are well over 100 different species of crops grown in the Windward Islands. Table 3 indicates those most commonly found.

* Each crop is attacked by some pest and/or disease; Table 4 shows the major pests and diseases.

* Every farmer grows more than one crop at a time on his farm, some as many as eight simultaneously.

* The Windward Islands, located in the warm, humid tropics, are a happy hunting ground for plant pests and pathogens. Therefore at any time of year, farmers are experiencing a pest attack on one crop or another.

Since the mid 1950s, plant protectionists (especially entomologists) have increasingly insisted that their science should employ a more holistic approach. Considerable progress has been made and ecological considerations are generally viewed as primary parameters in modern crop protection. Plant breeders have increasingly worked with entomologists, and agronomists have come to play an important role. However, a broad farming systems view has seldom been utilized by plant protection researchers. Such a broad understanding and the associated on-farm research is, however, an ideal way of defining priorities and directing crop protection work (Andrews, 1990).

It has become a cliché to say that crop protection procedures must be compatible with the natural environment, that is, must work within the limitations set for us by the laws of nature. It is less commonly acknowledged but no less true that the social and economic laws which govern human interactions must be recognized and accepted if we are to institute technological change. Socio-economic and political considerations affect what can and cannot be done at the farm level. An understanding of these 'non-technical' parameters is essential if crop protection is to be relevant and applicable, particularly to small-scale, resource-poor farmers. Some of the most overlooked factors which contribute to making the small-scale farmer resource poor are as follows.

Land

The first essential factor for production is land. In the Windward Islands, land distribution is highly skewed: a small number of landholders own a disproportionately large area, while large numbers of farmers tend smallholdings (Table 5). The smallholdings tend to be located in the more marginal areas where slopes, fertility levels and meteorological conditions are relatively disadvantageous. Additionally, as farm size decreases, a larger proportion of the land tends to be held under an insecure tenure arrangement. Larger farms tend to be owned, not rented, while the opposite is true of small-plot holders. More recently, increasing demands from the housing and tourism sectors, able to pay high prices for land, are placing even more pressure on the limited land available and forcing small-scale farmers further into the remote areas (Dominica Banana Growers' Association, 1990). The topography is not entirely conducive to the implementation of many standard crop protection practices: the rough terrain, steep slopes, high rainfall and predominantly clay soils all contribute to rapid wash-off and run-off of pesticides, difficulty in using application equipment, rapid development of pests and diseases, and rapid growth of weeds.

Table 3 Major crops grown in the Windward Islands

1.	Coconut	18.	Yam
2.	Banana	19.	Sweet potato
3.	Grapefruit	20.	Ortaniques
4.	Dasheen	21.	Anthuriums
5.	Oranges	22.	Tangerines
6.	Limes	23.	Ginger
7.	Tannia	24.	Lucky lily
8.	Mango	25.	(*Aloe vera*
9.	Coffee		(Cereal grains
10.	Cocoa	26.	(Sugar crops
11.	Avocado		(Legume crops
12.	Bay	27.	Nutmeg
13.	Plantain	28.	Arrowroot
14.	Passionfruit	29.	Spice
15.	Cassava	30.	Cloves
16.	Irish potato	31.	Vegetables
17.	Hot pepper	32.	Herbs
		33.	Sorrel

Table 4 Major pests and diseases of the more common crops grown in the Windward Islands

Crop	Disease/nematode	Insect pest
Araceae: Colocasia, *Xanthosoma* spp. (taro, dasheen, eddoe)	*Erwinia carotovora* Mosaic virus *Phytophthora colocasiae* *Pythium* complex	*Aphis gossypii* *Corytucha gossypii* *Cosmopolites sordidus* *Pseudococcus adonidum* *Spodoptera* spp.
Capsicum annuum (pepper)	*Alternaria solani* *Colletotrichum piperatum* *Erwinia carotovora* *Glomerella cingulata* *Meloidogyne incognita*	*Diabrotica bivittata* *Aleurotrachelus trachoides* *Nezara viridula*
Citrus spp.	*Diaporthe citri* *Elsinoe fawcetti* *Gloeosporium limetticolum* *Glomerella cingulata* *Mycosphaeralla horii* *Phytophthora citrophthora* *Phytophthora nicotianae* var. *parasitica* *Tylenchulus semipenetrans*	*Aonidomytilus albus* *Chrysomphalus* spp. *Coccus* spp. *Diaprepes* spp. *Exophthamas* spp. *Icerya purchasi* *Planococcus citri* *Saissetia oleae* *Taxoptera aurantii*
Cocos nucifera (coconut)	*Phytomonas staheli* *Phytophthora palmivora*	*Eriophyes guerreronis* *Rhynchophorus palmarum*
Coffea spp. (coffee)	*Armillaria melea* *Cercospora coffeicola* *Glomerella cingulata* *Fusarium stilboides* *Mycena citricolor*	*Cocous viridis* *Leucoptera coffeella* *Planococcus citri*
Cruciferae (cabbage, cauliflower)	*Erwinia carotovora* *Meloidogyne incognita* *Xanthomonas campestris*	*Aleurotrachelus trachoides* *Plutella xylostella* *Hellula phidilealis* *Ascia monuste* *Veronicella* spp.
Curcubitaceae (cucurbits)	*Colletotrichum lagenarium* *Erwinia carotovora* *Erysiphe cichoracearum* *Meloidogyne incognita* *Peronospora parasitica* *Pseudomonas lachrymans* *Sclerotium rolfsii*	*Aphis gossypii* *Diaphania hyalinata* *Spodoptera frugiperda* *Diabrotica* spp. *Aleurotrachelus trachoides*
Dioscorea (yam)	*Glomerella cingulata*	
Ipomoea batatas (sweet potato)	*Coleosporium yamoea*	*Euscepes postfasciatus* *Cylas* spp.
Lycopersicon esculentum (tomato)	*Alternaria solani* *Cladosporium fulvum* *Fusarium oxysporum* *Meloidogyne incognita* *Phytophthora infestans* *Pseudomonas solanacearum*	*Aleurotrachelus trachoides* *Liriomyza pensilla* *Nezara viridula* *Manduca sexta* *Thrips tabaci*

Table 4 continued

Crop	Disease	Pest
Mangifera indica (mango)	*Glomerella cingulata* *Phyllosticta* sp. *Oidia* sp.	*Ceroplastes rubens* *Chrysomphasulus aonidum* *Sternochetus mangiferae*
Musa spp. (banana)	*Fusarium oxysporum* f.sp. *cubense* *Mycosphaerella musicola* *Pseudomonas solanacearum* *Radopholus similis* *Rotylenchulus* sp.	*Cosmopolites sordidus*
Persea americana (avocado)	*Phytophthora cinnamoni*	
Theobroma cacao (cocoa)	*Botryodiplodia theobromae* *Fusarium regidiuscula* *Phytophthora palmivora* *Rosellinia bumodes*	*Xyleborus* sp. *Selenothrips rubrocintus*

Labour

On small farms, human labour is the most important and often the only power source. Labour requirements for agricultural work are notoriously variable according to season. Many farmers try to plan their production based on the possibility of obtaining enough hand labour at these key times. Another problem is that labour-intensive cultural practices may be required on the resource-poor farmers' crops at precisely the same time as lucrative employment opportunities become available off the farm. The cash flow from such employment may be essential for the family, but the opportunity cost of resulting absences due to increased pest and weed damage may be substantial.

There has been a migration of labour from the agricultural sector into the construction industry where the wages were better. As a result, farm labour has become scarce and expensive, and is arguably the most limiting factor to farm production (Dominica Banana Marketing Corporation, 1990). The labour time requirement for normal, routine farm operations is high and already takes up most of the farmer's working week. Control of pests and diseases is often regarded as an additional labour cost - whether the use of a pesticide or the implementation of some cultural measure, it often involves the use of extra labour or the working of longer hours by the farmer.

Capital

Capital is the third classical factor of production. Scarcity of capital severely restricts the productivity of many small-scale farmers. A typical Windward Island farmer has access to little more than a cutlass, fork and spade. Banana farmers fare better than others as, through their Banana Associations, they are provided with credit or inputs including fertilizer, pesticides or applicators. The more successful medium- to large-scale banana farmers may also own their own trucks (Dominica Banana Marketing Corporation, 1990). For small farmers the most important capital factor in annual crop production may be seed, and farmers tend to measure profitability and productivity in terms of return on this investment. Thus they often rate direct pests of the seed as very important.

Crop protection inputs are expensive: an average knapsack sprayer costs about US$ 150, a motorized knapsack about US$ 650, and pesticide costs range between US$ 10 and 25 per litre. As a result, many farmers only apply these inputs when there is an outbreak of a pest or disease (but often by then it is too late). Alternatively, if they are also banana farmers, they may use inputs from their bananas in their other crops, with the result that both crops receive less than optimum levels of input, and control is less than satisfactory.

Table 5 Distribution of land by size of holding, Commonwealth of Dominica

Size of holding (acres)	Number of farmers	Total acreage
< 1/2	1136	<200
1/2-1	897	521
1-5	4298	10 306
5-10	1601	10 356
10-20	577	7 330
20-50	179	5 016
50-100	101	9 529
> 100	10	5 000

Management ability

Farming in the tropics requires considerable managerial ability especially where diversified, ecologically sophisticated agroecosystems are involved. Small farmers usually manage a mix of annual and perennial crops as well as animals on small plots of marginal land under highly variable conditions, within an adverse socio-economic context. However, the management abilities of a small-scale farmer may already be stretched to their limits. The modern world makes all kinds of new demands on the traditional system, and the quality and quantity of natural resources available to the traditional farmer are rapidly decreasing: top soil, water, trees etc. (Rainey, 1987). Any crop protection methodology that requires a high level of management skills and critical decision-making based on data collected by monitoring crops is less likely to be accepted and implemented by small-scale farmers.

THE CROP PROTECTION DILEMMA

The Caribbean and the Windward Islands do not have a long history of agriculture nor of crop protection. Less than 500 years ago, tobacco was introduced into the region, followed by sugar cane, then cacao and citrus, and now banana is the predominant crop. Imported along with these crops were the production technologies - how to prepare the land, plant, cultivate, harvest, process and how to control pests and diseases. There was little scope or time for the development of indigenous crop protection practices, because the essentially chemical-based crop protection was, as far as possible, transferred to the small holdings. Today farmers are faced with a dilemma: on one hand, the largely imported crop protection methodologies presently employed, which essentially are pesticide-oriented, can only be described as at best inconsistent and at worst incompatible with the farming systems; on the other hand, there are few tried and tested alternatives available that are appropriate to the needs and resources of small-scale farmers.

There are a number of fundamental issues contributing to the crop protection problems facing small-scale, resource-poor farmers.

(i) Over the past 25 years we have been trying to impose on traditional farmers, many of whom are subsistence farmers, crop protection measures which originated in 'developed' countries for the conditions obtaining in those countries. Many of the basic crop protection methodologies are incompatible with the agroecological or socio-economic conditions in the islands, or are technically difficult and economically impossible to implement effectively. Examples include host eradication, crop rotation, introduction of exotic natural enemies, quarantine, rogueing, heat treatment, refrigeration, and soil treatment or fumigation. For example, most soil-acting pesticides are designed to be applied and incorporated into the soil by mechanical tractor-driven equipment on flat land; not to be dug into the soil with a fork on steep hillsides. The limited experience of aspects of classical IPM in the islands has not been very successful, and has led to the following observations:

* the small size of holdings makes the effective use of non-residual chemicals difficult because neighbouring plots serve as sources of reinfestation

* natural enemy manipulations are less than optimally effective because of the movement of pesticides and pests into the plot, and because of the migration of natural enemies

* many cultural and mechanical controls suffer from the same limitations

* time invested in scouting to take the minimum number of samples can be cost prohibitive.

(ii) The second issue is that most of the crop protection specialists in these islands have been trained either in developed countries or in regional institutions whose curriculum and standards are adapted to those in developed countries. Crop protection scientists in the Islands are continually trying to adapt outside technologies to suit local conditions - very often with less than satisfactory results. These specialists have often recommended crop protection measures which are inappropriate to the resources available to the small-scale farmer or to his/her farming system and conditions. There are very few tested alternatives to the classical crop protection methods available for recommendation to small-island farmers.

(iii) The third issue is the high-impact advertisement campaigns of the chemicals companies. Farmers are constantly bombarded with the alleged 'benefits' of a variety of pesticides - in the press, on radio and on TV local agents hold demonstrations and entice farmers with 'specials' and prizes. This has resulted in many farmers spending scarce resources to purchase products that are inappropriate to their needs and conditions, which often give inconsistent results and may even contribute to or aggravate the pest problem.

(iv) The fourth issue is the high quality standards demanded in the 'developed' markets for our agricultural exports. Small-scale farmers are put under tremendous pressure to attain these quality grades, and they have no choice but to purchase fertilizers and pesticides to produce the crops for export. Recently,

Table 6 Production inputs acquired (1989, 1990), Dominica Banana Marketing Corporation

Materials	Unit	Quantity		Percentage change
		1989	1990	1990 over 1989
Fertilizers	tons			
Compound fertilizer		8 473	10 651	+25.7
Calcium ammonium nitrate		1 206	500	-58.33
Muriate of potash		-	-	-
Triple super phosphate		-	-	-
White lime		174	323	+85.6
Herbicides	litres			
Paraquat		119 825	30 000	-74.96
Gramocil		-	6 600	+100
Gramoxone (paraquat)		20 000	96 240	+381
Reglone (diquat)		48	5 580	+11 525
Round-up (glyphosate)		720	2 160	+200
Talent (tallow amine ethoxylate)		-	238	+100
Extravon (alkyl phenolethoxylate)		-	200	+100
Nematicides/Insecticide				
Primicid (pirimiphos-ethyl)	litres	26 300	10 000	-61.97
Furadan (carbofuran)	kg	100 000	-	-100
Mocap (ethoprophos)	"	58 320	58 320	-
Nemacur (fenamiphos)	"	1 250	8 540	+583
Miral (isazofos)	"	-	1 467	+100
Vydate (oxamyl)	gal	1 100	8 000	+627

even the local market is starting to demand minimum quality standards: these standards are being set using those in more developed countries as examples. This has led to the development of 'Tech Packs', a wholesale prescription for all farmers to follow, irrespective of their own soil type, climate, crop mix, slope of land, etc. - this is no doubt a convenient methodology, but it is also an impractical and unscientific one.

The banana industry is by far the largest user in the Islands of chemical fertilizers and pesticides (Table 6), which make a significant contribution to the high cost of production and the low competitive status of the banana industry. Also, because of the industry's high profile, it 'educates' farmers on production practices, which are then transferred to other crops.

A fifth issue could be cited but is more complementary than fundamental to the crop protection problems facing the small-scale, resource-poor farmer: many internationally funded agricultural projects provide free pesticides and other agrochemicals as major components of their agricultural development projects. This helps keep farmers in the pesticide habit and makes them less receptive to alternative crop protection methodologies.

A sixth issue is the lack of adequate research in appropriate pest management strategies.

STRATEGIES FOR IMPROVEMENT OF CROP PROTECTION

I will now attempt to describe a crop protection approach that could be adopted in these small, resource-poor islands. It involves tackling five areas of deficiency.

Technology generation

There is a dearth of indigenous, applicable crop protection technology in the Islands. Other than the work done on cocoa by Pendergras & Weir in the1950s, on citrus by Hussain & Beddoe in the 1960s, on nursery propagation by the Inter-American Institute for Co-operation on Agriculture (IICA) and on coffee research by Janice Reid of the Caribbean Agricultural Research and Development Institute (CARDI) in the early 1980s, the only current crop protection research being carried out in the Islands are projects on mango, avocado, citrus and coffee (funded by CARDI and the ODA's British Development Division in the Caribbean), and on bananas (funded by the Windward Islands Banana-Growers Association, WINBAN).

Traditional small-scale farmers may have a 'feel' for ecological interactions and an intuitive appreciation of the rationale of pest management, even if it is not often that these attitudes can be consciously or systematically expressed. There are some traditional production/protection practices which can be used as the firm foundation for better-developed pest management programmes.

Cultural practices which can be developed and promoted include the following.

(i) Habitat diversification involving intercropping, relay planting schemes and live fence rows. These practices provide important refuges and sources of natural enemies, and crops suffer much less damage due to pests and diseases than under monoculture production.

(ii) Destruction of crop residues either by burning, incorporation in the soil or feeding to animals. This practice is especially important in control of pests such as stem borers, and in removing sources of inoculum for diseases.

(iii) Farmers also often plant by moon phase. This so-called 'superstition' is, in fact, well founded in those areas where large noctuid larvae (cutworms) can cause damage to seedlings. The traditional planting time is the full moon, the time when a large proportion of the population is entering the non-damaging prepupal and pupal stages.

(iv) The use of traditional varieties, many of which exhibit a high degree of resistance or tolerance to pest attacks - much more so than certain high-yielding new varieties.

(v) The judicious use of pesticides, in particular the more specific, less toxic, non-residual types, to control pest or disease build-up.

Nursery management

The management of propagation nurseries is generally poor, with inadequate procedures in place to prevent the development and control the spread of pests and diseases. As a result, many plants are distributed from these nurseries infested with pests and/or diseases. Serious investment and work needs to be put into improving this aspect of the crop production system.

Networking

The technicians in the Windward Islands are largely unfamiliar with research efforts being undertaken on similar crops in other developing countries of the tropics. This is due not only to the geographical separation and language barriers, but also because there is no institutionalized mechanism in place to bring the technicians together or for sharing the results of their work. This meeting could hopefully start the process of south-south networking. Funds are needed to facilitate reciprocal visits and meetings of technicians from developing countries.

Training

There is always a need for training. Unfortunately, technicians in the Islands are often unaware of training courses being offered, and even if they have the information, finance is difficult to obtain.

Agro-processing

Crop protection is directly related to marketing. The approach is based on the following assumptions.

* These small islands cannot compete successfully on the world market in any of the crops that they currently produce for export. This is due firstly to the small aggregate acreage of the crops in comparison with their competitors, and secondly to the high cost of production, mainly caused by the high cost of the crop protection measures currently practised. The net result is that the islands cannot compete, either on volume or on price.

* The small islands therefore have to gain access to other, non-traditional markets. Two of these are (i) the ethnic market in the UK, USA and Canada, which is less demanding of cosmetic appearance in agricultural produce, and (ii) the growing world-wide market for 'naturally' or 'organically' grown food.

The Islands have received millions of dollars in aid for the production of crops, significantly less for the marketing of these crops, and little or nothing for one area that offers some hope for the survival of agriculture: agro-processing. Growing crops for export as fresh fruit places pressure on farmers to use expensive crop protection measures in order to attain the high quality standards of these export markets. Growing for processing significantly reduces the costs of crop protection and offers the farmer an alternative long-term viable outlet for his production.

The two general economic goals of all farmers are: (i) to maximize the rate of return on the investment of limited resources, and (ii) to stabilize production in such a manner that certain basic needs are always met. The first goal may be called 'profit maximization', the second 'risk aversion'. For crop protection innovations to be adopted by resource-poor farmers, they must both be inexpensive and promise a high rate of return.

CONCLUSIONS

There is a need for more research aimed at solving the problems faced by small-scale resource-poor farmers, carried out with the farmers and on their farms. This also requires a change of approach in the training of our scientists, not only by the regional University of the West Indies, but also by UK universities such as Reading University and the University of London (Wye College and Imperial College), where many students from developing countries take degree courses. Students should be encouraged and assisted to do research projects for their degrees in their own countries, to build up a series of locally developed crop protection technologies as viable alternatives for farmers.

A workshop such as this is a welcome step in the right direction of developing crop protection strategies for resource-poor farmers. Too often in the past, technical assistance specialists have arrived in our countries without proper or adequate preparation and sensitization to the situation in small countries, and have plunged straight into their preconceived notions of the problems facing the farmers, often using equipment and levels of inputs that the average small-scale farmer is never likely to afford. This effort at attempting to understand the resource constraints under which small-scale farmers have to operate, and to appreciate why they do what they do, will go a long way to making future contributions to crop protection for resource-poor farmers more meaningful to both scientists and farmers.

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DISCUSSION

I. Haines (*ODA, London, UK*). There is a need for us to reconsider 'clean crops'. In the developed countries we need to accept more produce with cosmetic damage, although I know that the large supermarket chains are very reluctant to do that - the supermarkets tend to say that the general public will not accept it. What advice can you give us about persuading people to accept more produce with cosmetic damage?

U. W. Martin. It is very difficult, because we are competing with countries that have million dollar advertising budgets. They can influence the public to believe that a smooth yellow banana is desirable, whereas we know that freckled bananas are the really good bananas. It is a question of money. The organic natural food drive that is going on is very slow, and is going to take a long time to really capture a sizeable proportion of the market. One of the ways for the small islands to survive in the future is to try to tap these 'natural' markets that are beginning to develop, because otherwise we will not be able to survive the increasing costs of production, caused by the high costs of pesticides.

J. C. Reid *(CARDI , Kingston, Jamaica).* I would question your statement that students who have gained PhD and MSc qualifications in the west are irrelevantly trained. However, on the point just raised, I think we agree that the organic market may be a market to go into. But in developed countries, organically grown food is in many cases still relatively blemish-free - perhaps these organic growers have some lessons in crop protection and production for us.

I also want to stress the last point you made about agroprocessing, because I think we are still hooked on the business of marketing fresh fruit to countries that really do not use them as fresh fruit. We could circumvent a lot of problems by going into first-stage processing.

K. Pouono (*Department of Agriculture, Forests and Fisheries, Apia, Western Samoa*). You mentioned that some of the major pests in the Windward Islands are exotic pests - does that have implications for quarantine?

My second question is on the definition of resource-poor farmers. A banana farmer, for example, may be given funds to control pests and diseases but may use that fund for other purposes - is that farmer really 'resource-poor'?

U. W. Martin. In relation to the first question with regard to exotic pests: we do have serious problems with some of our major crops, for instance our mangos may be infested with mango seed weevil and fruit fly. The result is that we cannot export any mangos to US countries - one of our major markets for mangos was the US Virgin Islands but we have since lost that market because of quarantine restrictions. Grenada is presently facing some problems with US quarantine in terms of internal seed feeders of crops like soursop (although they have been declared free of the fruit fly). The Caribbean Basin Initiative (CBI) and other such organizations were set up to encourage the Caribbean islands to export to the USA, but every time we make a move forward, another barrier is erected in the guise of quarantine. Quarantine is a serious problem for us in the islands, because most of our exports are fresh fruit exports.

In terms of the banana situation, yes I would still say that the banana farmers who receive credit are resource-poor, because the only reason they have inputs is the existence of the credit scheme. If they had to pay for inputs they would not buy them. That is evident in that a lot of the banana farmers also grow other crops like citrus, mangos, vegetables, root crops, and do not buy inputs for these other crops, although they may use some of the inputs for the bananas in these other crops.

J. W. Bentley (*Escuela Agricola, Pan Americana, Tegucigalpa, Honduras*). You mentioned that there is no area-wide group that meets to talk about pest problems, and I was wondering if you had considered the Central American and Caribbean Programme for Food Improvement (PCCMA) which meets every year in different Central American or Caribbean cities to discuss technical aspects of tropical agronomy?

U. W. Martin. We are aware that there are groups of people who meet in other parts of the world, but we have no system in place to allow us to attend these meetings. It is really a question of funding and, often, also a question of ignorance of what is going on. What I am suggesting is some system where we could have regular contacts between Africa, south-east Asia and Latin America. There is no institutionalized form of establishing these links.

P. Nkunika (*Department of Biology, University of Zambia*). I want to comment on your suggested strategy on training. If our teachers are indigenous people, there will be disagreement on whether to use IPM or technologies that reflect the teacher's specific background.

U. W. Martin. The point I am trying to make on training is that most of us in crop protection have been trained outside the region. It is only very recently (three years ago) that our regional university started an MSc crop protection programme. The problem is that most of us who were trained outside come back with crop protection methodologies which are often not directly compatible with the systems of our countries - we may have trained on apples or grapes or cherries, and know nothing about the mangos and avocados that are in our own country. I am suggesting that we need to find a way of local training - one way it can be done is to allow students to do their project work for their degrees in their own country.

A. A. Seif (*KARI, Nairobi, Kenya*). The ultimate objective of taking a higher degree is to acquire the capacity to do independent research, not to concentrate specifically on national programmes or national problems (although there are options whereby part of a degree could be of more relevance to specific topics that would be experienced at home). Once a student has gained that capacity, he or she should be able to modify that training to suit the local conditions.

U. W. Martin. Provided the facilities are available locally.

E. A. Babiker (*Ministry of Agriculture, Khartoum, Sudan*). With all the pressures on small farmers (lack of inputs, high cost of inputs, lack of capital), is help needed from governments to keep them in the system, and if not, what do you feel their future will be?

U. W. Martin. Presently all the ministries of agriculture in the four islands have plant protection sections whose main function is to train farmers in controlling and identifying pests. Governments' funds are limited - they usually provide some inputs at subsidized prices, but that is not sufficient to service all the farmers and all their problems. So as we mentioned earlier, what happens is banana farmers, who can obtain inputs through their banana associations on credit, may use some of these inputs on other crops.

I do believe that pesticides will have a role to play long into the future, but I also believe that we have to devise a system where there is less need to use them, or where they are used only at the most critical times. Most small-scale farmers are willing to accept a certain level of loss due to pests and diseases as normal, and would only really want to use pesticides when the problem starts to become serious. But very often, because of the high ratio of farmers to extension officers, information is received very late, often when it is too late to do anything about the problem. A lot of the classical IPM strategies such as the introduction of natural enemies have not worked because of the nature, size, closeness and distribution of the farms. For example, the way farmers grow their crops, cabbages next to tomatoes, next to melons, next to passion fruit, means that although a natural enemy is introduced for a cabbage pest, if there is no natural enemy for the tomato pest, the farmer is going to spray his tomatoes anyway. So we need to encourage farmers to use cultural practices, to prepare the land properly, to plant at the right time, to drain (or irrigate) if they have a water problem, and use pesticides only when necessary.

The epistemology of plant protection: Honduran *campesino* knowledge of pests and natural enemies

J.W. BENTLEY

Department of Crop Protection, Escuela Agrícola Panamericana, El Zamorano, Honduras

ABSTRACT

Folk knowledge of the natural environment, including pest control topics, is highly uneven. Examples from Honduran peasant farmers show that rural people have extensive folk taxonomies and much cultural lore for relatively conspicuous organisms that are of perceived cultural importance, such as social bees and wasps. Conspicuous but unimportant subjects, like sphecid wasps, fit into shallow taxonomies and have less community knowledge associated with them. Important but difficult-to-observe topics, such as bean leaf diseases, may have poorly developed folk taxonomies, and are sometimes linked with beliefs that are incongruent with western science. Unimportant and difficult-to-observe creatures such as parasitic wasps are generally neither known nor named. This scheme allows pest control workers to classify organisms, whether natural enemies or pests, according to the level of community knowledge, and to anticipate the unique opportunities and challenges that each kind of folk knowledge offers.

RESUME

La connaissance populaire de l'environnement naturel, y compris des sujets relatifs à la lutte contre les fléaux, est très inégale. Des exemples recueillis parmi les paysans Honduriens montrent que les ruraux disposent de taxonomies populaires étendues et de beaucoup de connaissances sur des organismes relativement visibles qui ont une importance culturelle reconnue comme les abeilles sociales et les guêpes. Des sujets visibles mais sans importance, comme les guêpes sphécides, s'intègrent bien dans des taxonomies superficielles et la connaissance de la communauté en ce qui les concerne est moindre. Des sujets importants mais difficiles à observer comme les maladies des feuilles de haricot peuvent avoir des taxonomies populaires peu développées et sont parfois liés à des croyances incompatibles avec la science occidentale. Des créatures sans importance et difficiles à observer, comme les guêpes parasites, ne sont en général ni connues ni nommées. Ce programme permet aux agents de lutte contre les fléaux de classifier les organismes, qu'il s'agisse d'ennemis naturels ou de ravageurs, selon le niveau des connaissances dont dispose la communauté et d'anticiper les opportunités et les défis uniques que chaque genre de connaissance populaire offre.

INTRODUCTION

> "People usually do not classify exhaustively unless organisms are important or conspicuous. The Fore of New Guinea have a single word for all butterflies, although species are as distinct as the birds they do classify in Linnaean detail." (Gould, 1980)

In this brief statement, Stephen Jay Gould identifies the two most important factors that influence the development and complexity of folk taxonomies: importance and conspicuousness. I would further emphasize that it is not enough for a set of organisms to be important or conspicuous: they must be important *and* conspicuous or people will fail to classify them extensively. The really deep and rich folk taxonomies and the impressive bodies of folk knowledge are those for organisms (or other things or ideas) which are important and conspicuous. As Gould's example shows, conspicuous butterflies are not treated to an exhaustive taxonomy because they are not important.

In this paper I define 'important' as meaning 'of perceived value or harm to the local people', including economic use and physical pain. For example, humans perceive wasps as important because their stings hurt and occasionally kill people. Whether or not a creature is conspicuous or easily observed depends on its size, colour, movements, time of activity and perceived risk to the observer, and is also influenced by cultural attitudes (such as 'all insects are bad').

Importance and ease of observation can be visualized as two axes which divide folk knowledge into four cells, with different taxonomic structures and unique classes of knowledge (Figure 1). In the upper right-hand cell of the figure are the important, easily observed topics like social insects, weeds, farm tools and

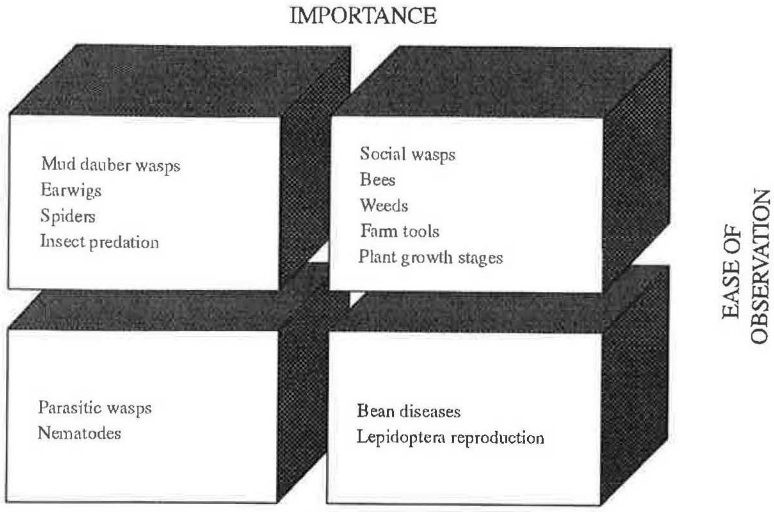

Figure 1 Four classes of farmer knowledge

plant growth stages. These domains are rigorously classified and well understood. The upper left-hand cell includes easily observed but unimportant entities like the Fore's butterflies and, for Honduran *campesinos* (peasant farmers), earwigs, spiders and mud-dauber wasps. These animals are named but are neither highly differentiated taxonomically nor connected with much cultural lore. The lower right hand cell includes important but difficult-to-observe topics such as many plant diseases and lepidopteran (moth and butterfly) reproduction. These are named and, although not split into many folk categories, are the focus of cultural beliefs which may be at odds with western science. The lower left hand cell holds unimportant and difficult-to-observe topics like parasitic wasps, which *campesinos* are generally unaware of, and do not name.

Although many of my prime examples come from insect taxonomy, this division of kinds of knowledge can account for much indigenous technical knowledge about the natural environment. This scheme is about ideas rather than biological organisms *per se*. Some organisms are easy to classify according to one of the four classes of knowledge, while others must be teased apart. Honduran folk knowledge of ants, for example, falls in at least two classes: stinging behaviour and seed eating are in the 'important, easy to observe' class, while ant reproduction and predation fall in the 'unimportant but easy to observe' cell (Figure 1). Ant reproduction is easy to observe - as *campesinos* kick open ant nests they notice the ants scurry off with larvae. Farmers understand that, like bees, ants care for their young in nests, but the notion is of little practical value to *campesinos*. I have arbitrarily classified ant predation in the 'unimportant, easy to observe' class, but it shares some properties with the 'unimportant, difficult to observe' class. Because *campesinos* do not know that ants prey on insects, ant predation is not perceived to be important. But when they find out that ants help control pests, the idea does become important. Although ant predation is potentially important, and easily demonstrated, *campesinos* do not notice it for at least three reasons:

* it is not as obvious as ant reproduction, as the ants often forage at night and hunt over large areas (while ant reproduction takes place in small, discrete places)
* a cultural bias that insects do not eat other insects discourages the observation
* much of the prey taken by ants is early instar larvae and insect eggs, so is not very easy to see.

CLASSES OF KNOWLEDGE

Conspicuous and important: 'thick taxonomies'

Conspicuous and important phenomena tend to be organized into many folk categories, in a taxonomy five or six layers deep (see Figure 2). Conspicuous and important organisms are often labelled at the biological species level. Explanations of these phenomena - the quality of honey, the painfulness of wasp stings - are often couched in 'positivist' terms, that is, the explanations are consistent with scientific knowledge and acceptable to scientists.

While it may seem obvious that important, conspicuous things are better understood and split into more categories than unimportant, inconspicuous items, much of the debate in ethnoscience has revolved around the relative importance of morphology and economic use in determining nomenclature (Hunn, 1982; Turner, 1988), with less attempt to reconcile or synthesize both perspectives. There has been such a strong tendency to study the important and conspicuous that ethnoscience gives the impression that all of folk science is profound and highly ordered. Several motives lead anthropologists to study folk taxonomies. One is the search for cognitive structure (either universal or culture-bound) in semantics. Human universals in the organization of folk taxonomies suggest that all peoples see the world in comparable ways (Berlin, 1973; Brown & Chase, 1981; Hays, 1983; Boster, 1987). Documenting detailed semantic paradigms satisfies our desire to demonstrate the intellectual equality of all humankind and helps anthropologists portray the (generally poor, marginalized) people they have studied as intelligent, observant and thoughtful. Ethnoscience, the branch of anthropology most concerned with folk taxonomies, has highlighted many examples of detailed folk knowledge of nature. Examples include studies of animals (Hunn, 1977), insects (Wyman & Bailey, 1964) and soils (Behrens, 1989). Berlin's work on Tzeltal folk botany (Berlin *et al.*, 1974) is often cited as an example of how peasant farmers know the names of, and uses for, thousands of plants.

Profound knowledge is not limited to living beings. Honduran *campesinos* name each part of common agrarian implements like ploughs and yokes in great detail. Elsewhere I have described how small-scale Honduran farmers precisely divide the stages of a maize plant's growth cycle by a series of about eleven verbs, comparable to the numbered vegetative and reproductive stages of maize phenology used by agronomists (Bentley, 1989). Current work with entomologist Ronald Cave shows that Honduran *campesinos* generally categorize social bees to the species level. *Campesinos* must gauge bee defence strategies and honey quality to decide whether to chop down a tree down and split it open for honey. The European honey bee, which stings, was introduced by the Spaniards to Central America (and recently replaced by an Africanized sub-species); native American bees are stingless but each species has a defence mechanism. Some retreat into their nest when disturbed, and peer out of the entrance, others swarm the intruder, delivering hundreds of bites on the face and neck. One species secretes a burning liquid onto an attacking vertebrate's skin. Honey quality is as variable as the type of defence the bees mount. *Campesinos* classify various kinds of honey as medicinal, good to eat, nasty and potentially poisonous. The honey of at least one species is spurned because people see the bee foraging on dog faeces. Hondurans distinguish over half a dozen small, black bee species at the level of the biological species. Much like entomologists, who use keys or diagnostic differences to separate taxa, *campesinos* sort bees by the unique features of architecture (generally the shape of the nest entrance), behaviour (especially how they enter and leave the nest), and morphology. For example, *campesinos* notice that the diminutive, golden *quema quema* (*Trigona*

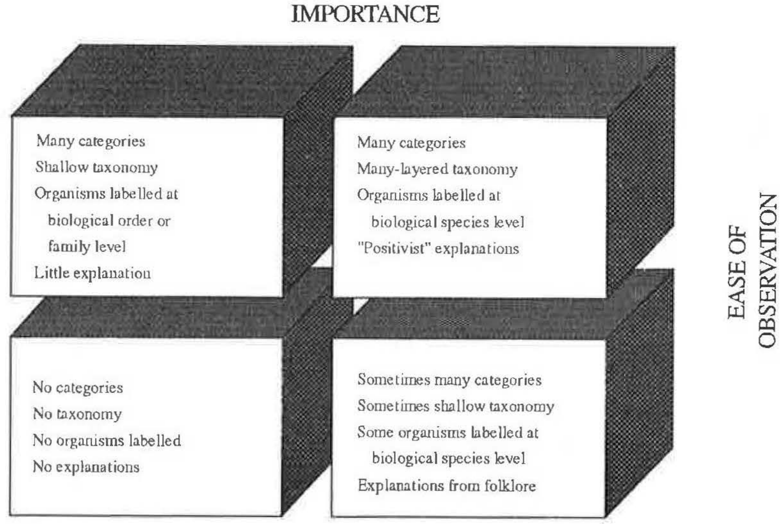

Figure 2 Characteristics of four classes of farmer knowledge

pallens) (Hymenoptera: Apidae), which oozes poison and visits dog dung, has green eyes, distinguishing it from the *jimerito* (*T. jaty*), a mild-mannered, medicinal honey maker.

The Vespid family, better known in English as 'paper wasps' for their intriguing fibrous nests (Hansell, 1989) is classified with almost as much attention. *Campesinos* recognize that some species are so tame they can live under the eaves of houses, staying in permanent association with people without stinging. Others hurl themselves on passers-by and sting viciously. One tiger-coloured species (*Protopolybia acutiscutis*), about the size of the housefly, is known as the 'underwear remover' (*quitacalzón*) because a horde of the wasps silently and systematically crawls throughout the victim's clothing before launching a painful stinging attack that raises welts many times larger than the wasps. People who can't leap into a river are often forced to strip. Some wasp stings are said to induce fever and one is alleged to cause choking. As if these different levels of pain and aggression were not enough reason for rural folk to label vespids at the biological species level, one species of *Brachygastra* also produces up to a gallon of honey, which is harvested. A couple of *Polybia* species make smaller amounts of honey, and some people toast their larvae to eat.

Just as *campesinos* can discriminate between related bee species when they have a good reason to, they may lump together social wasps that are economically similar. A good taxonomist can distinguish *Polybia occidentalis* from *P. diguetana* by putting them under the stereoscope and scrutinizing their yellow stripes. *Campesinos* differentiate them by nest shape: one is oval and the other is longer. Although rural Hondurans recognize the two species as different, they give them the same name, because their difference is not important, both are mild-mannered, have only moderate stings, and produce tiny amounts of honey. Many species of *Polistes* and *Mischocyttarus* are all lumped together with one folk name (e.g. *catala*), although *campesinos* easily admit that there are different kinds, which they can distinguish by colour, size and nest habit. The difference between these wasps is not considered important; they make no honey and are not especially aggressive. Although *campesinos* generally perceive wasps as important, the poorly distinguished ones are near the fuzzy cognitive border between the halves of nature which are perceived as important or unimportant.

Conspicuous but unimportant: strings of folk genera

Conspicuous but unimportant phenomena are often classified in a taxonomic structure with many categories, but few levels - shallow strings of dozens of names with no subordinate and few superordinate categories (see Figure 2). Conspicuous but unimportant organisms are often labelled at the biological family or order level. There is little attempt at explanation, positivist or otherwise, for phenomena in this group.

As much as we like to portray traditional rural people as able taxonomists, exhaustive studies of folk taxonomies often reveal many animal names with little paradigmatic structure. Hunn (1977) found that for Tzeltal speakers of Mexico, 106 of 335 individual names for animals were classed as birds, another 45 as mammals, while 184 names, many of which were insects, were not included in higher taxonomic levels (except for that of 'animal') and most of the 335 names include no subdivisions.

I use the phrase 'folk genus' for the term linguistic anthropologists call 'generic taxon', as an analogy to the Linnaean genus. In any language, folk genera form the most important, basic, cognitively salient taxonomic level (e.g. English 'fly') and are occasionally divided into folk species (e.g. 'house fly', 'horse fly'). Folk and scientific taxonomies are both formal classificatory schemes, but they contrast in two important ways: inclusion of sub-categories and treatment of Linnaean species. While most Linnaean genera are subcategorized into several species, most folk genera are not. Many folk genera correspond to Linnaean species (e.g. English folk genera 'horse', 'sheep' and 'maize') while others correspond roughly to the biological family (e.g. 'ant', 'mosquito', 'grass') or order category (e.g. 'dragonfly', 'earwig'). Some folk genera, like the English 'butterfly', include several families but not the whole order.

Honduran *campesinos* do not think of any bugs (terrestrial arthropods) other than honey producers as beneficial, so most insects are classified in a shallow taxonomy and are given folk genus names with no species subdivisions. *Campesinos* lump the entire order of Dermaptera (earwigs) together as *tijerillas* (little scissors), just as most spiders are undifferentiated *arañas* and all dragonflies (order Odonata) are merely *caballitos del diablo*, 'the devil's little horses'. Being conspicuous is no guarantee of even a unique name for animals with no perceived economic importance. The mud-dauber wasps (family Sphecidae) are highly conspicuous, building nests shaped like organ pipes, footballs and mud clods on houses and other buildings. *Campesinos* see the wasps hauling spiders or grasshoppers into the nests and know that they rear their young there, but because sphecids are useless and harmless to *campesinos* they are merely lumped into the residual category 'just wasps', sharing the name avispa with the vespids and other wasps. Many *campesinos* claim that sphecids have no name, or that they do not know it.

Important but difficult-to-observe: the enigmas

Important but difficult-to-observe phenomena may or may not have complex taxonomies, depending on biological factors (see Figure 2). For example bean diseases in Honduras are poorly classified, with viral and fungal disease, nutritional deficiencies and other ailments all grouped together. Some insect pests are classified at the biological species level, although knowledge of their behaviour, especially of their reproduction, may be poorly understood. 'Folkloric' explanations (e.g. spontaneous generation), often at odds with positivist science, are much more common than they are for other kinds of knowledge.

Nothing is more maddening than a real problem with no obvious solution, like many insect pests and crop diseases. Multiple diseases are more difficult to observe and differentiate than one disease. *Campesinos* confuse many bean diseases (Bentley, 1991) but because there is only one major maize disease in Honduras, maize ear rot, farmers are able to focus on the disease and acquire a body of knowledge comparable to that of plant pathologists. Honduran *campesinos* have formed the same hypotheses as specialists for solving this disease problem, including increased soil fertility, quicker drying of the grain, burning crop residues, and bending the maize plant over (Bentley, 1990).

Voracious worms that seem to appear fully grown from nowhere, others that descend on a field by the thousand overnight and diseases that wipe out whole fields rank high on the importance scale, but are hard to observe. Magico-religious explanations or other 'odd' unscientific-sounding beliefs about insects and other organisms are likely to occur in the important but difficult-to-observe cell.

Although insect pests are some of the few insects other than bees and wasps which *campesinos* classify at the biological species level, farmers have a poor understanding of caterpillar reproduction. The *cogollero*, or whorlworm (*Spodoptera frugiperda* - Lepidoptera: Noctuidae) is an endemic maize pest which *campesinos* perceive as chronically lowering crop yields. Because it is very tiny when it first hatches and glides through the air on a silk thread, landing inconspicuously on the earth and making its way to maize plants, *campesinos* do not notice the *cogollero* in its early instars. They notice the little windows the tiny larvae carve in maize leaves, eating off the green tissue and leaving a transparent film in the centre, but many fail to distinguish those windows from the damage of leaf miners, a host of small insects of different orders which work in the completely opposite way, by eating out the interior of the leaf. *Campesinos* notice whorlworms when they are large caterpillars eating the tender new tissue of the maize whorl, and burying themselves in their own faeces. Farmers believe that the worms are generated spontaneously by the corn plant itself, citing as evidence the fact that smashed whorlworms are green, like maize plants (see Bentley & Andrews, 1991).

One of the odder beliefs about insect pests in Honduras involves the gregarious grasslooper, *Langosta medidora*, (*Mocis latipes* - Lepidoptera: Noctuidae). Because it completes its life cycle in 19 to 36 days (King & Saunders, 1984) and lives in wild grasses, it can appear overnight in certain maize fields. Although maize is not the grasslooper's preferred food, if it runs out of favoured grasses the third or fourth generation after the start of the rainy season may hit a farmer's maize field like a disastrous act of God. Coming as though from nowhere, the masses of chewing caterpillars can turn a ripening corn patch to bare stalks and central veins in a day or two. Rural folk around Danlí, Honduras, believe that a field attacked by medidora can be saved with a magico-religious rite called *cruzar la milpa* (crossing the corn field). The praying practitioner walks diagonally through the field both ways, sometimes sprinkling holy water and usually making little crosses of maize husks or worms in the corners and centre of the field. Then the owner is told not to go into the field for nine days and the worms will disappear. Keith Andrews (Crop Protection Department, El Zamorano, personal communication, 1988) points out that nine days is just long enough for the medidora to pupate and disappear as if by magic. While he tends to see an element of chicanery in this practice, I don't. The farmers I talked to suggested that the ritual specialists were only paid a labourer's day's wages. 'Crossing a corn field' gives some Honduran farmers a supernatural support that provides the psychological comfort to get on with farming. Although the rite is practised in a relatively small area of eastern Honduras along the Nicaraguan border, it is spreading into the Valley of Jamastrán, which was settled recently by migrants from southern Honduras, where the practice is unknown. It may strike plant protection specialists as ironic that a magical practice can spread spontaneously while many of our technologies are not adopted after massive extension efforts.

So far I have discussed material factors (size, mobility etc.) which influence how easy an organism is to observe. Cultural attitudes also affect how people see the world around them, even though those attitudes may have been shaped in part by the biological structure of that world. For example, Hondurans, both *campesinos* and most of the middle class, believe that all insects are bad except bees. Virtually all insects are thought to be herbivorous. While this belief may have a basis in the observation of abundant plant-eating insects in the tropics, it also affects *campesinos*' vision of their fields as being virtually under siege to insect pests. Farmers over-react to the relatively large, brightly coloured, diurnal *Diabrotica* spp. beetles. Although crop scientists believe that the beetles rarely do economic damage, *campesinos* often apply pesticides as soon as they notice *Diabrotica* in their fields.

Difficult-to-observe and unimportant: the empty quarter

Because difficult-to-observe and unimportant phenomena are not usually categorized, they fit into no folk taxonomies and are not labelled at any levels of biological classification (see Figure 2). They are accompanied by no folk explanations. Many organisms are neither named nor paid any attention to, because they are both difficult to observe and not perceived as important. Because they are so small, often microscopic, none of the four major families of parasitic Hymenoptera in Honduras is even recognized by farmers, let alone seen as pest controllers. Each herbivorous insect has at least one parasitoid wasp, and sometimes dozens, as well as nematodes, flies and other tiny organisms whose lives are intertwined with the host they feed on and kill. If not for these little creatures, Central American farmers would starve; yet the wasps are neither named nor known. While sitting with a pair of farmers in a maize field a parasitic wasp landed on my knuckle. Seizing this opportunity to see how farmers perceived this natural enemy, I held my hand up to one of the men and asked him what it was. "It's an ant," he said, as he smeared it into my finger.

NATURAL AND INTELLECTUAL ENVIRONMENTS

This framework of farmers' knowledge attempts to balance the anthropologists' wonder at indigenous knowledge with the technocrats' bias that peasant farmers are ignorant and superstitious. Before going on to discuss how the four classes of knowledge can inform participatory technology generation, I argue that the farmers' natural and intellectual environments call for technology generation with farmer involvement.

Some smaller geographical regions, like Central America, have more environmental variation than scientists can design IPM technology for (Andrews & Bentley, 1990). There is important environmental variation even within a single community: some farms are much larger than others, some fields lie along river banks and others on fragile hillsides. There is an almost infinite number of agrarian environments, each with different pest profiles and research demands.

Many farmers are innovators who think creatively to solve their own problems. Virtually all farmers try new crop varieties. The irrigation systems built by Honduran *campesinos* are feats of community engineering. Each one is a work of art, tailored to a particular stretch of rough country, carrying water thousands of metres from canyon streams, around hills and over precipices. Farmers in central Honduras have recently invented a horse-drawn plough, a narrow hoe for cultivating garlic, and a triangular hoe to dig trenches for chemical fertilizer. Many similar farmer innovations from Honduras and other countries could lengthen this list. Farmer creativity is a potential resource for solving problems in diverse natural environments - and 'farmer participation' is now cited so often that its arguments hardly need be repeated.

However, the farmer participation trend has created more rhetoric than results. While sociological differences between researchers and farmers (Chambers, 1983) may be largely responsible, there may be other, less obvious reasons why farmer involvement has so far failed to live up to its promise. There may be an implicit assumption that, as farmers are wise and creative, their participation is uniformly helpful and is limited only by the researcher's commitment to collaboration. We need to consider how farmers have different depths of knowledge for different kinds of knowledge, and that farmer-scientist interactions should be shaped by the pattern of knowledge (Figure 3).

RECOMMENDATIONS FOR RESEARCH AND DEVELOPMENT

Important and easy-to-observe

As this class includes farmers' most familiar topics, this is where scientists can learn the most from them. Rhoades' (1989) familiar example of diffused light potato storage falls into this class. Scientists learned about the technology from farmers in Kenya and successfully spread it to farmers around the world (see page 12).

Farmers are expert at intercropping, a traditional practice now widely assumed to limit pest populations by increasing environmental diversity, providing habitats for natural enemies and making it harder for the phytophagous insects to find food (Altieri, 1987). Sustainable weed control must be based on technologies without herbicides or fossil fuel; traditional weed control with manual and animal-drawn tools is the obvious starting point for such technologies.

Just a few of the other topics where science can learn much from traditional peoples include:

* management of native American meliponid bees, raised since pre-Columbian times
* behaviour of other large social insects
* use of smoke to protect seed maize from weevils
* pharmaceutical and nutritional value of 'non-weeds' and other wild plants.

Farmers' knowledge should especially be relied upon to set research agendas, instead of allowing scientists'

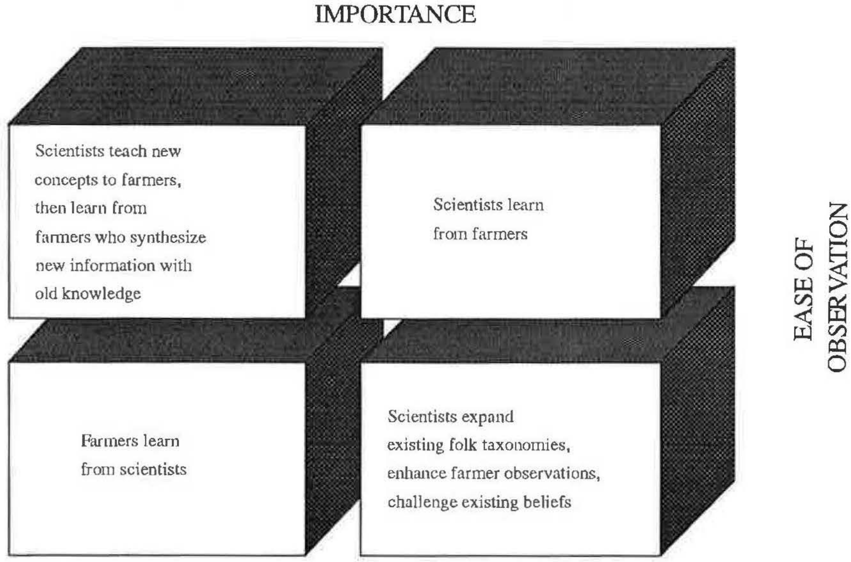

Figure 3 Style of participation according to class of knowledge

often esoteric disciplinary interests to drive research. (Unused maize-drying buildings in Honduras, abandoned water harvesters in Arizona's Papaguería [Bentley, 1987] and failed, large-scale, capital-intensive irrigated rice schemes in West Africa are just some of the monuments to planners' and scientists' arrogance.)

Not important but easy-to-observe

This class may offer the greatest opportunity for collaborative research. By teaching farmers things they do not know about certain easily-observed organisms, farmers may gain an enhanced perception of some of the species around them, and then learn more about them by continued observation. Some topics - mud-dauber wasps, defoliating caterpillars on wild plants or mushrooms - are easy to observe but unimportant to farmers, and to most scientists too. Other topics offer a source of new ideas for both scientists and farmers. The most obvious example is the predatory insects. Because earwigs, social wasps, ants, certain true bugs (Hemiptera) and praying mantises are easy to observe, if we let farmers know that these creatures help control crop pests, they can teach themselves how to conserve and manipulate these natural enemies. Farmers often gratuitously destroy wasps and ants to avoid being stung. A farmer who kicks apart an ant nest forces the ants to waste energy rebuilding the nest, possibly even using their own larvae as emergency rations instead of preying on armyworms and other pests. Scientists often feel obliged to develop a technology to extend to people. In his keynote address to this seminar, Robert Chambers criticized this notion, arguing that we should extend precepts, not packages (see page 12). The 'unimportant but easily observed' class of knowledge is especially suited for extending precepts. Teaching farmers that ants eat insects gives them a reason to see ants in a new light, re-evaluate them as natural enemies and then learn how to manipulate them.

In Honduras my colleagues and I use bee, wasp and ant reproduction as a starting place for discussing insect metamorphosis with farmers; explaining fly reproduction (which they partially understand) and moth and beetle reproduction (which they do not understand) in terms of hymenopteran reproduction (which they do understand).

Scientists can help shift farmers' notions of insect predation from the unimportant to the important side of the chart, by teaching them about it. As farmers blend new information with old knowledge and new observations, they may create new, synthetic ideas and technologies which scientists would not have invented. We experienced one such case in Honduras. The entomologist Keith Andrews attempted an experiment with the predatory *Polybia* spp. wasp, moving hives onto maize fields, but was frequently stung and most of the wasp colonies soon absconded. Andrews abandoned the idea in the early 1980s. Not long afterward he explained wasp predation to a group of farmers, and one of the farmers, Wilfredo Flores, began moving nests. In 1989 another entomologist, Ronald Cave, and I discovered that Flores had begun moving nests on his own. *Campesinos* traditionally move nests from brush to avoid being stung while clearing land. They start learning about wasp relocation as children, bringing hives into rural schoolrooms and releasing them, hoping to terrorize the teacher and other students.

Important but difficult-to-observe

This class represents the greatest challenge to scientists because it sometimes implies changing beliefs rather than adding new information. It is a heterogeneous class where I have identified three styles of intervention (expanding existing taxonomies, enhancing farmer observation, and challenging existing beliefs).

Expanding existing taxonomies

When I first came to Honduras in 1987, some agronomists ridiculed the *campesinos*' use of the word 'ice' (*hielo*) for plant disease (see Bentley, 1991). The agronomists mistakenly thought that farmers believed that their crops froze. After Guillermo Cerritos and I studied the problem and explained that 'ice' labels most plant diseases but does not imply that the plants actually freeze, many agronomists who work with farmers adopted the term. At least one successful extension agent, Werner Melara, explains to farmers "as you know, there are many kinds of ice" and then explains the different symptoms and causes of various diseases, essentially filling in a traditional category, 'ice', with a new taxonomy of 'fungus, virus, bacteria', etc.

Enhancing farmer observation

If farmers are interested in a topic and lack the tools of observation to fully appreciate it, one tactic is to share novel methods of observation with them. In a study of maize ear rots, the major disease of maize in Honduras, we found that *campesinos* know virtually all that phytopathologists know, except for the causal agent (Bentley, 1990; del Río, 1990). So in over a dozen villages in the remote interior we set up a microscope and showed the fungus to *campesinos*, and we explained how this kind of fungus was like mushrooms that they were familiar with, but smaller. We then invited the *campesinos* to suggest possible control tactics. They proposed dozens of ideas, of which we eventually tested three for control of the disease: burning crop residues, bending the maize plant or removing leaves or tassel at physiological maturity, and trials of (native) maize varieties.

Challenging existing beliefs

This may be more difficult. Many Honduran *campesinos* say that agrochemicals spontaneously generate insect pests. They say that the first pests were seeded in chemical fertilizer so the people would be forced to buy insecticide, but each one they bought contained the seeds of yet another pest, trapping the farmers on a conspiratorial chemical treadmill. If farmers realized the true relations between pesticide and pest populations, they may be able to wean themselves off agrochemical dependency. Farmers understand very well that physiological traits are inherited by the offspring of people, livestock and crops - and they readily grasp the idea of insects being selected for genetic resistance to pesticides. Farmers also accept the idea that natural enemies are killed by insecticides. After a week with a group of farmers, I congratulated myself on having spent days carefully building a logical framework for changing the idea of spontaneous generation that was nevertheless consistent with the local culture. In a final discussion, however, one of the farmers suggested, and the others agreed, that agrochemical companies seed insects in products. We still have a lot to learn about changing existing beliefs.

Unimportant and difficult-to-observe

On the other hand, adding completely new concepts is easier. Although *campesinos* do not know about parasitic wasps, they enjoy the topic. We use photographs and live parasites in bottles to expose *campesinos* to the subject. We also find it easy to introduce farmers to the notion of entomopathogens by analogy with humans: just as people get sick and sometimes die because of disease, so do insects. We show farmers cadavers of insects killed by disease. This subject offers promise because of the growing importance of biological insecticides as alternatives to chemicals. Basic knowledge about disease may help farmers accept the biological control agents, even though they take days instead of minutes to kill pests.

CONCLUSIONS

I have suggested that gaps in indigenous technical knowledge can be predicted using a two by two matrix of 'importance' and 'ease of observation'. A similar matrix that took into account the tools of observation and occupational interests of other groups could be used for fishermen, bus drivers, bankers, entomologists and others. While farmer participation in research is now widely promoted, it has failed to live up to its initial promise and has generated few technologies. Honestly confronting the limitations as well as the strengths of indigenous technical knowledge may help scientists have more fruitful interactions with farmers.

Technical collaboration with farmers should be based on learning what the people know and what they don't know, figuring out what they need to know, teaching it to them in a way that is consistent with what they know, and then learning from them as they synthesize new information with old knowledge.

ACKNOWLEDGEMENTS

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DISCUSSION

J. Farrington (*ODA, London, UK*). The work you are doing with farmers looks very interesting, but what kind of wider-scale application does it have for scientists - are you thinking of some kind of training programme, for example, where they are taken through similar experiences themselves, or are you going to produce a manual that they could work with - what is the bridge between your field experience and a wider programme to influence the way scientists behave?

J. W. Bentley. We are doing a course on biological pest control based on these notions, developing different ideas in different ways, according to how farmers perceive them to begin with. An example of something well known to farmers that is important and easy to observe, is weeds - farmers know that weeds compete with crops, yet people earning good salaries waste their time writing pamphlets explaining that weeds compete with crops, take up nutrients, take up water, compete for sunlight - the farmers know all this, and the agronomists are wasting valuable resources. A topic as difficult to perceive as parasitic wasps must be explained to farmers - they can understand it, but it has to be explained very carefully. At least in Honduras, farmers do not understand that there are insects which eat other insects - the lack of that knowledge is the source of much pesticide abuse in Central America. It is important to realize that farmers do research on their own, they do a lot of experiments, and can think of a lot of technologies on their own. If we just enhance their knowledge with more ideas, they will do better experiments and will come up with a lot of technology that we cannot come up with.

P. Nkunika (*Department of Biology, University of Zambia*). How long have you been working on this project, and how long do you expect it to continue? How do you see perceptions of knowledge developing over that time?

J. W. Bentley. The work has been going on for four years, and we expect it to continue for a further three to five years, and maybe more. My perception of the farmers has changed with time. I started with the 'ethnoscience' bias - I thought farmers knew everything. But that was because I was an anthropologist working in isolation. When you start to work with biologists, and they set you a research agenda to ask farmers about parasitic wasps, and entomopathogens, and things an anthropologist would never think of, then you find that farmers do not understand these things. My first experience in Honduras was very frustrating, as I found that there were many things farmers didn't know, which seemed to reconfirm the agronomists' bias that farmers know much less than they do. Out of frustration I started to look where the light was brightest, at topics that I knew farmers understood, and only after that was I able to put this scheme together. Often in plant protection we are working on topics where we know more than the farmers do, but we should not let that give us a sense of false security, that we are smarter than them, because we have microscopes, and professional meetings like this one. As far as how the farmers' perceptions are changing, that is hard to tell, but they are very interested. They are fascinated by natural enemies, and it is great fun to demonstrate to farmers how ants and wasps eat insects, and to learn with them in the field.

N. D. Jago (*NRI, Chatham, UK*). The sort of things you are learning about farmers' ignorance also help us to understand our own ignorance - Dr Chambers' presentation demonstrated how closed all our minds are. Knowledge can come from many sources - on our project in Mali, we live in the millet fields, and through wandering around in the fields at night we accidentally learned that the millet head miner moth males sing to the females, which turned out to be a very important discovery. Neither farmers nor researchers normally see what is happening in the field at night.

Constraints on the introduction of new techniques for resource-poor farmers

F. M. WAMBUGU

*Kenyan Agricultural Research Institute, National Agricultural Research Centre, Muguga, PO Box 30148, Nairobi, Kenya**

ABSTRACT

Resource-poor farmers in developing countries experience many constraints, including yield losses due to insect pests and vectors, and to diseases. Constraints on the introduction of new techniques and technologies to alleviate the situation of these farmers can be better understood by considering where the new techniques would be directed within the current farming systems. Such techniques are directed towards improved control of weeds, diseases, and insect vectors and pests, and are implemented at land preparation, planting, crop growth, harvesting and storage. In most cases these farmers lack the basic information and finances needed to utilize the new techniques and technologies to their advantage.

RESUME

Dans les pays en développement, les paysans disposant de peu de ressources connaissent un grand nombre de contraintes, dont les pertes de rendement dûes à des insectes nuisibles et à leurs vecteurs, ainsi qu'à des maladies. Les limitations de l'introduction de nouvelles techniques et technologies pour améliorer la situation de ces paysans peuvent être mieux comprises si l'on examine l'orientation des nouvelles techniques au sein des systèmes de cultures actuels. De telles techniques visent à arriver à une meilleure lutte contre les adventices, les maladies, les vecteurs et les fléaux et elles sont mises en oeuvre lors de la préparation des terres, des semis, de la croissance des cultures, de la récolte et de l'entreposage. Dans la plupart des cas, les paysans manquent de l'information fondamentale et des ressources financières nécessaires pour tirer parti de ces nouvelles techniques et de cette technologie.

INTRODUCTION

Before considering the constraints of introducing new techniques and technologies to resource-poor farmers, it is important to note that, although these changes are highly desirable, there is a need to introduce them with caution and with clear understanding of the sustainability of the proposed development. Feasability studies are needed to determine how the new procedures will affect farmers, and particularly the resource-poor, on the question of whether they will derive economic benefits, whether they will need extra inputs (such as pesticides and fertilizers) to achieve those benefits, and whether there will be technical difficulties in integrating the new technologies with existing farming systems (for example, in the introduction of the new virus-free materials from tissue culture).

Furthermore, there is a need to understand the farmer's knowledge and cultural practices regarding the problem in order to facilitate possible integration with new disease control strategies. For example, from 1989-90 I was involved in a survey in Kenya on sweet potato, particularly on virus diseases. I visited farmers in the areas where sweet potato is an important crop, in Western, Eastern, Central and Coastal Provinces of Kenya. The concept of virus diseases is difficult to understand, so I needed to listen carefully to the farmers to find out how the problem was experienced in the performance of their crops. Although farmers did not recognize the virus disease, they knew when a plant was 'sick', and practised positive selection for healthy looking plants when choosing planting materials. Later in my studies, I found visual positive selection was a very effective field virus-control strategy when combined with the use of virus-free planting materials.

The relative importance of technology to production and marketing also needs to be assessed, especially to determine whether there will be a net yield increase, a reduction in production costs, a premium price for the products, and/or other marketing advantages for the small-scale farmer. The possible contributions of new techniques in the conservation of natural resources such as soil and water, effects on pesticide and fertilizer requirements, and effects on the environment need to be better understood. An especially important issue for a country like Kenya is the effect of agronomic practices on wildlife.

*Present address: Monsanto Co., 700 Chesterfield Village, Parkway, St Louis, Missouri 63198, USA.

POSSIBLE NEW TECHNIQUES - ADVANTAGES AND CONSTRAINTS

Considering the current farming systems, I will present some examples of constraints on new techniques which are becoming increasingly available to farmers. Other speakers at this seminar have discussed related cases such as integrated pest management (IPM) and biological control. I will also highlight some of the advantages and constraints, particularly as they affect the resource-poor farmer.

Land preparation

At the land preparation level, the new technique of zero tillage by using herbicides has certain advantages: control of soil erosion by conserving soil moisture; control of some plant diseases, especially where weeds are alternative hosts; and saving on labour costs. The small farmer may be constrained by lack of basic information on these techniques, lack of finances to purchase the necessary machinery, and lack of safety measures needed for the application of herbicides. In Kenya, zero tillage has been adopted by many coffee farmers because coffee is a cash crop and the big co-operative farms can distribute herbicides and machinery, and can give other advantages to the farmer. The small-scale farmer does not have access to such facilities, so subsistence food crops such as beans, sweet potato, etc. cannot benefit from zero tillage in the present circumstances.

Planting material

For planting material, new techniques involve:

* use of treated, certified seed bought from commercial companies
* use of virus-free plantlets and cuttings produced through tissue culture by commercial companies
* control of soil-borne diseases using pesticides
* planting disease-resistant hybrids and clones
* crop rotation and fallowing.

These techniques have the obvious advantage of controlling the introduction of new diseases. However, the small farmer is constrained by the high costs of treated certified seeds, pesticides may be too expensive, his/her land may be too small for rotation or fallowing, and even basic information on the new techniques may be lacking.

Virus-free and disease-resistant hybrid plants may not be readily available to small-scale farmers in developing countries. An example is coffee-growing in Kenya, where an improved hybrid resistant to coffee berry disease and leaf rust has been produced. The hybrid was developed over ten years' research in Kenya and is now available on the market, but seedlings cannot be produced fast enough. Those available are taken first by the big corporations, and then by the richer farmers, and are very unlikely to reach the small-scale farmer. So the resistant hybrids go first to those who can afford them, not to those who would benefit most. In developing countries, techniques and facilities for tissue culture may not be available, and could be too expensive to run. So for small-scale farmers in developing countries, tissue culture as a method of propagating clean planting material is really not an obvious option. However, there is a success story in Kenya where tissue culture techniques are being used commercially to increase the planting materials of pyrethrum (*Chrysanthemum cinerariaefolium*, a commercial flower used to produce natural pesticides) and to control root knot nematodes (*Meloidogyne* spp.). The marketing agency called the Pyrethrum Board of Kenya, a government organization, adopted rapid micropropagation techniques developed by the Kenyan Agricultural Research Institute (KARI). In collaboration with KARI they established rapid micropropagation laboratories to make plants produced by tissue culture available to small-scale farmers. This is a good example of a high-technology method made available simply to farmers, as healthy plants with economic benefits. Similarly, big corporations and farmers working together in a group may be able to introduce and utilize new technology, but there has to be some support from professional institutions, whether they be governments, donor agencies or national research stations.

Plant growth

Control of diseases, insect vectors and pests with pesticides, rogueing of infected plants and volunteer plants, weed control by use of herbicide applications, and forecasting before pesticide applications are all new, improved crop protection techniques. These techniques have the advantages of controlling the fungal and bacterial foliar diseases, reducing viral diseases (through controlling insect vectors such as aphids), and controlling plant insect pests such as stem borers. Disease forecasting before pesticide applications also helps to save on costs.

The small-scale farmer's constraints may include the high costs of pesticides, machinery and safe clothing for applications, a lack of basic information on the use of the pesticides, e.g. which are preventative or curative, and when best to apply pesticides to keep costs to a minimum (i.e. forecasting). Farmers are unwilling to rogue disease-infected plants and volunteer plants, which later become foci for disease dispersal. They will practise positive selection to avoid the 'sick plant' when planting, but find it difficult to rogue these once they are established in the field, as they expect some yield. It may also be true that there is a lack of knowledge on the real reasons for rogueing.

Harvest

There are new techniques of harvesting generated by scientific research which take into consideration crop maturity, moisture content, minimizing harvesting damage, use of harvesting machinery, and seed treatments before storage. But this knowledge is not accessible to small farmers, who also lack finance for the purchase of basic machinery and pesticides.

Storage

New techniques on proper storage of particular crops to prevent losses due to diseases and insect pests involve consideration of the height of the storage facility above ground, construction materials, humidity, temperature, aeration, lighting and roofing. Pesticides may also be required to control storage diseases and insect pests, but their use by these farmers may be limited by lack of finances. The small-scale farmer may experience constraints such as a lack of information on the proper storage facilities for particular crops, even when such methods are cheap and affordable. One specific example is of a potato storage facility designed in Kenya by the International Potato Centre (CIP). An effective storage structure was developed of simple and cheap materials, with a grass thatched roof, which can extend the storage life of potatoes by four months. When I asked potato-growing women's groups in a meeting whether they were using this technology, it was clear that very few knew anything about the structures. So it is not just the cost, since this structure was affordable. In this case, farmers did not have the knowledge necessary to use the structures, and so did not benefit. Dissemination of information to small-scale farmers is very important.

FUTURE BIOTECHNOLOGY FOR FARMERS IN DEVELOPING COUNTRIES

The new techniques and possibilities of biotechnology, such as the *in vitro* biosynthesis of plant-cell products, the introduction of disease- and pest-resistant genes in plants, and the introduction of herbicide-resistant crops, will benefit developed countries. It is likely that the impact of biotechnology on farmers in developing countries will be minimal or possibly negative. For example, by studying the biochemistry of the metabolic pathways, cotton fibres have been produced *in vitro*, with the goal of commercial production. Similar studies are under way for tropical crops such as pyrethrum, coffee, tea and tobacco. The cotton manufacturers are unlikely to care whether their cotton comes from a test tube or from Africa, and the same is to be expected for other crops. Also, it should not be expected that the costs of biotechnology products from the commercial companies of developed countries, such as disease- and pest-resistant crops, will be any cheaper than pesticides to resource-poor farmers. Under these circumstances, there is a need for the developing countries to take an interest in and sponsor the development of relevant, affordable and beneficial technologies, in order to assist their farmers.

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DISCUSSION

M. G. Kariaga (*Crop Protection Research Co-ordinator, Nairobi, Kenya*). My first comment is on the 'success story' of pyrethrum. The root-knot nematode *Meloidogyne* is polyphagous and can survive on a number of plants in the farmer's plot - seedlings which have been produced by tissue culture are soon reinfected when they are planted out into farmers' fields. The only alternatives we have identified are either to leave the land fallow or to plant another crop which is resistant to *Meloidogyne.* There are not many such crops and unfortunately the farmers cannot leave their lands fallow because they are resource-poor as far as land is concerned.

My second comment is on rogueing as a control measure. It is true that a lot of farmers resist roguing - I have experience on sugar cane where the main control measure is to rogue. Where farmers uproot stalks, the pathogen remains in the stalks and, as the farmers do not understand the reason for rogueing, they lay these stalks with all the pathogens along the line, and of course people tramp on them, which spreads the inoculum.

F. M. Wambugu. My comments about the first 'success story' were based on micropropagation; as I said, the nematode elimination was really a side benefit and we did realize there was a possibility of tissue-cultured materials having problems of re-infection when returned to the field. However, as it was the same pyrethrum germplasm that was being used, changes in susceptibility due to the tissue culture process could only be established through research, by comparing traditional split planting materials, and this has been done. The achievement of having a micropropagation unit in Kenya, which acts as a model for other crops and flowers, cannot be underestimated. Many visitors from developed countries who see this micropropagation unit are impressed and surprised because they do not expect it in Africa.

P. Jowah (*Cotton Research Institute, Kadoma, Zimbabwe*). As far as the new techniques and technologies are concerned, what would happen if we change the approach? For example, if a country wants to build a dam, they will first carry out an environmental assessment of whether it is applicable in that particular case, before introducing a new technique. Should we make an assessment of the constraints we are likely to meet before we put forward the technology?

F. M. Wambugu. A sort of feasability study is necessary to answer certain crucial questions. One of the recommendations in my talk was that a micropropagation unit based on rapid multiplication of virus-free sweet potato materials could be used to replace the very seriously degenerated materials farmers are using in some areas. For example, the average yields of sweet potato in developed countries in 1979 were 14 t/ha, as compared to 6 t/ha in Africa, possibly due to virus diseases. At the same time, the sweet potato yields were estimated at 9 t/ha in Kenya, 6 t/ha in Tanzania and 5 t/ha in Uganda. The question is, if we decide we are going to do micropropagation for virus-free sweet potatoes, how do we introduce this to the farmers? Are the farmers going to benefit? How is this going to fit in their current farming system? Do they need training, and are there going to be technical difficulties? How sustainable is that project going to be? And once the project runs out of donor funds, how are the farmers going to continue with this project? How long are these materials going to stay in the field before they are re-infected to an uneconomic level?

S. M'Boob (*FAO Regional Office for Africa, Accra, Ghana*). I still have a problem with your methodology. I understand that all these basic questions should be answered first before we launch a project, but this is just the problem. I do not think the solution is sitting down in our laboratories and asking these questions. I will give you an example to illustrate my point. In the early 1970s we had a very serious stem borer problem on sorghum in The Gambia, and one of the first things we talked about was resistant varieties. We did succeed in developing a beautiful resistant variety, but all this time was spent in the research station. When we went and distributed this seed, the farmers grew it the first season and said it was very nice, but then they went back to their old varieties. Why? Because they did not like the colour of the grain - they do not like red sorghum, they like white sorghum. If we had involved the farmers right from the beginning of our testing, we would have found out that they do not like this variety because it is red. Going through this list of problems is a good idea at the planning stage, but if we do not involve the farmers and go ahead and deliver this technology, invariably we run into problems because they were not involved.

F. M. Wambugu. Of course, I agree with that completely and I think after yesterday's presentations we have all been converted. There have been difficulties, and I can give one example. IITA had the mandate for developing or improving sweet potatoes for Africa, and they spent quite a lot of time and input on breeding sweet potatoes for Africa in Nigeria. But breeders know you cannot breed the material in Nigeria and take it to Kenya. Finally some materials were distributed and taken to Kenya, and there is not a single plant from IITA that has been grown by Kenyan farmers. The only cultivar introduced to farmers (KSP20) disappeared because of fast virus re-infection and degeneration, and is now only found in the research stations. It does however have good marketable qualities, and grows near the base, but the farmers say it is very soft to eat and does not store well in the ground for piecemeal harvest, as practised by most farmers. Information on farmers' preferences is very important when improving a crop. A lot of time and resources can be spent improving a crop, but if the farmer does not accept the final product, then it is all wasted.

Different constraints on individual and community action

J. ROWLEY

OXFAM, 274 Banbury Road, Oxford OX2 7DZ, UK

ABSTRACT

Poor farmers have not been well served by conventional research, extension or other development programmes aimed at improving pest control. This is despite the important effects of pests on their production, and the enormous importance of poor farmers in food production for their own survival and for the stability of many areas of the world. Part of the reason for the failure of conventional approaches is a failure to take account of the diversity, complexity and high-risk nature of the production systems of poor farmers. Complex diverse and risk-prone (CDR) production systems cannot make use of generalized advice or initiatives that might be applicable to more homogeneous situations. For many reasons a much greater input is required to identify appropriate innovations that might be useful to CDR farmers than for farmers in more dependable circumstances. For these reasons, private companies, governments and individual scientists are reluctant to commit themselves to work with CDR farmers. Gradual and marginal improvements are the only realistic aims of such work; revolutionary change is probably impossible. Examples from a number of situations in Africa are used to demonstrate successes that conform to CDR farmers' needs and perceptions; these examples tend to show innovations that are low cost, low risk and require few new skills. The need to respect very localized conditions and to identify measures that reduce risk at low cost imposes new approaches to survey work, project planning, training, etc. Communal work is often associated with low-cost risk reduction and some examples are used to illustrate where such an approach has been appropriate to particular circumstances. Community participation can be crucial to the success of pest control operations, but successful communal control often occurs where social cohesion exists or is acquired before being turned to pest control. Nevertheless, counter examples demonstrate that under special conditions, social co-operation can be generated through the pest control activities. Failure is more common where the initiating body has found itself simultaneously confronted with the twin tasks of promoting the necessary social cohesion and the pest control activities. Attempts to find solutions through social engineering (the social fix) appear as absurd and unworkable as attempts at technological solutions (the technical fix).

RESUME

Les paysans pauvres n'ont pas beaucoup bénéficié des programmes de recherche, de vulgarisation ou des programmes conventionnels de développement visant à améliorer la lutte contre les fléaux. Cela, malgré les effets importants que les fléaux ont sur leur production et l'importance énorme que les paysans pauvres revêtent en matière de production alimentaire pour leur propre survie et pour la stabilité de nombreuses régions du monde. L'échec des approches conventionnelles est dû en partie au fait que l'on n'a pas tenu compte de la diversité, de la complexité et des risques élevés inhérents aux systèmes de production des paysans pauvres. Des systèmes complexes, divers et à risques élevés ne peuvent pas tirer parti de conseils ou d'initiatives généralisés qui pourraient être applicables dans des situations plus homogènes. Pour un grand nombre de raisons, des intrants beaucoup plus importants sont requis afin d'identifier des innovations appropriées qui pourraient être utiles aux paysans dans ces systèmes de production à risques élevés, que pour les paysans vivant dans des circonstances plus sûres. C'est la raison pour laquelle les entreprises privées, les gouvernements et les chercheurs rechignent à s'engager dans des travaux avec les paysans vivant dans des systèmes de production complexes, divers et présentant des risques élevés. Des améliorations progressives et marginales sont probablement le seul objectif réaliste de tels travaux; un changement révolutionnaire est probablement impossible. Des exemples provenant d'un certain nombre de situations en Afrique sont utilisés pour démontrer les succès qui répondent aux besoins et aux perceptions des paysans vivant dans des systèmes de production complexes, divers et présentant des risques élevés. Ces exemples tendent à montrer des innovations à faible coût, présentant peu de risques et nécessitant peu de nouvelles compétences. La nécessité de respecter des conditions très localisées et d'identifier des mesures, qui réduisent les risques et soient bon marché, impose de nouvelles approches aux enquêtes, à la planification des projets, à la formation, etc. Les travaux communautaires sont souvent associés à une réduction des risques dont le coût est faible et certains exemples sont utilisés pour illustrer les cas où une approche de ce genre s'est avérée appropriée à des circonstances particulières. La participation de la communauté est parfois essentielle au succès des activités de lutte contre les fléaux mais, en général, il semble que la lutte communautaire soit couronnée de succès là où une cohésion sociale existe ou est obtenue avant d'être orientée vers la lutte contre les fléaux. Néanmoins, des exemples contraires montrent que dans certaines conditions spéciales, une coopération sociale peut être engendrée par les activités de lutte contre les fléaux. Toutefois, un échec est plus fréquent lorsque l'organe initiateur se retrouve confronté simultanément par la double tâche de promouvoir la cohésion sociale nécessaire et les activités de lutte contre les fléaux. Les tentatives visant à trouver des solutions par le biais d'une ingéniérie sociale (la solution sociale) semblent aussi absurdes et impraticables que les tentatives visant à trouver des solutions technologiques (la solution technique).

INTRODUCTION

There are many resource-poor farmers in the world and their production is important not only for their own survival, but also for the stability of huge areas of the world. Their numbers are increasing and the resources they rely on are decreasing; I hazard that resource-poor farmers are getting poorer. Despite this there is a paucity of resources being directed towards helping poor farmers. Governments do not want to invest in marginal agriculture; scientists (with some notable exceptions) do not want to work on the more intractable problems. More field work is required, more social science and multidisciplinary work is required, it takes longer to make any impact, and there is no push from the private sector because there is no market in selling to very poor people. I want to emphasize that the solutions to these problems require both institutional and personal changes; this seminar could make a resolution for longer project timespans which would be entirely appropriate, but it also requires that individually we make longer term plans and make recommendations for longer budgets when asked to vet other project proposals.

The lack of work in pest control for resource-poor farmers is emphasized by a recent report (Haverkort *et al.*, 1991) which looks at areas of work covered by field projects in low-external-input sustainable agriculture and at records carried in the main agricultural science databases. Of respondents in the field, only 11% said that their projects concerned pest control using local methods. In the CAB International database, while 5791 hits were made on animal traction and 1000 on agroforestry, there were only three on crop protection. Something is wrong: either there is no work going on, or the work is not being reported, or it is not being called crop protection.

It is appropriate for someone from a non-governmental organization (NGO) to address this meeting. OXFAM's mandate is the relief of poverty. Its role in carrying out pest control programmes is to protect or improve the standard of living of a particular group of people. It is also appropriate for an NGO speaker to talk about social organization and the constraints on individual and community actions: NGOs rarely make grants to individuals, but almost always to groups. The nature of these groups varies widely and plays a major part in determining the success or otherwise of new farming practices.

EXAMPLES OF GROUP ACTION

The OXFAM office

The coffee club in my office involves 15 highly educated people contributing weekly to the purchase of coffee, tea, milk and sugar for the office. However, the collective is badly organized and I have resorted to buying my own equipment to enable me to achieve my priority, which is to have a cup of tea or coffee exactly when I want it. This may seem a trite example, but it shows how collective action is sustainable only when individuals perceive it to be in their interests; in the case of coffee in the office, my best interests lay in individual action.

The project agro-forestier in Burkina Faso

The social organization of the Mossi people in Yatenga and to some extent their attachment to the land has predisposed OXFAM's project work there to being based on collective work. The work began as a forestry project to plant trees in an area of severe environmental degradation which had lost much of its natural tree cover. After the first season in 1979, tree planting was abandoned as the farmers indicated that they would rather use the soil and water conservation techniques for growing millet. The techniques were adapted for crop growing rather than tree growing and considerable improvements in yield were achieved. The techniques were acceptable because they tended to reduce risk and required very little in terms of new skills. The major input was labour and the existing social cohesion allowed communal work on individual and on communal fields to go ahead. The project activities have increased to include the growing of grasses and legumes along the contour bunds and, more recently, the enclosure of goats and composting which have helped to increase yields. This has made it possible to put resources into the growing of fodder crops for animals and into the growing of trees. Thus growing of trees has started in earnest ten years after the project started. So far there have been no sustained project activities focused on pest control.

Pastoral associations in Chad

OXFAM has been working in the Batha province of Chad with agro-pastoralists, focusing on animal health (the provision of veterinary drugs and the training of para-veterinarians) and on the provision of credit. The associations that seem strongest are those that have some basis in clan relationships and in which collective activities have been limited; mostly these have become the short-term use of credit to generate capital. It may be that the social organization of the herders works against collective actions, and that by trying to work with groups OXFAM is performing a form of social engineering.

This appears to be supported by the results of workshops carried out in another OXFAM project in Dori in northern Burkina Faso. In the workshops the herders rank the requirements for successful animal raising, and a consensus is emerging after the first three workshops involving herders from Burkina, Mali and Niger. Being a good herder, taking the care of animals seriously, is the most important requirement. Second is good grazing, third is water, fourth is minerals, fifth is good breeding stock, and health care for the animals (the equivalent of pest control in crop protection) is ranked as sixth. Associating with other herders is only the eighth requirement for success in animal rearing.

Cereal banking

OXFAM supports many agricultural communities through cereal banking which involves the provision of credit so that the group can buy their own production (Fall, 1991). This is done at a higher price than they might get on the market, which offers very low prices at harvest when farmers are obliged to sell grain for cash. The group can then sell grain back to themselves during the hungry period at a slightly higher price which allows the bank to make a profit, but again saves the farmers money as the market price usually rises to exorbitant levels.

The cereal bank is one way of promoting collective action which should provide benefits locally to the group. It should also help to stabilize production as it acts against the disincentive of very low prices at harvest. It is a tiny attempt at providing an economic pull on production.

Village brigades

The use of village brigades against migratory insects (grasshoppers and locusts) is one of the clearest examples of collective action in pest control. Collective action is necessary simply because of the scale of the problem during plague years. Agreeing to go some distance from one's fields in order to combat insect pests is a clear statement of collective working; the individuals are prepared to accept the possibility of personal loss for that of common gain.

In a report by the US Office of Technology Assessment (US Congress, 1990) there are three acounts of successful village brigades, all personal observations made in West Africa by outsiders. However this is not enough to convince me that this is sustainable community action. What is probably happening is that the communities are being motivated by strong personalities (village leaders or extension staff), and carry out the collective action in response to the individual's charismatic pull, rather than in response to a selfish analysis of the situation. This is a well-known phenomenon seen in trying to work with groups where none really exists; in OXFAM it is sometimes called the 'star' phenomenon, the leader being like a famous star.

Extension services in Ethiopia

I have observed a classical extension approach in Ethiopia where, despite the centre-led, technology-driven approach of extension, the interactions between the extension worker and the lead and follow farmers seemed to allow equitable exchanges of information. This has led me to think that the system is sometimes less important than the personal contact and the nature of the rapport between the different actors involved in promoting changes in techniques and production systems.

I could go on multiplying examples but they will only show that there is a range of different social settings through which external projects can work to enhance farming practices. There are truly communal groups where the individuals are inter-dependent and benefit individually from membership of the group. There are artificial groupings that work for the purpose of relating to the external project but which allow individuals to take their own decisions. There are the groups led by 'stars' and there are attempts at social engineering that work counter to the perceived needs of the individuals. As with technologies, so with social organization: there is no easy answer appropriate to all situations and each situation will have to be examined before effective techniques and effective social groupings can be identified.

PARTICIPATION

Participatory methods have shown that they are invaluable in this process of identification. It has been possible, despite great diversity and complexity, to identify coherent groups where group action is essential for the success of an initiative. It has been possible to identify conflicts that would make social groupings impossible and it has been possible to identify why many development initiatives have failed when not participating with the beneficiaries.

Do you believe that there will be a Green Revolution (technology-driven radical changes in production methods that would triple yields) in Africa in the next ten years? If not, you must accept that the improvements to the current situation of chronic shortages and fragile production will come about by incremental change; a gradual rise in productivity. If this is the case, those increases will be within current farming systems and will be under the control of farmers, and if we are to assist in that process we must participate with those farmers.

I think that we are in the middle of a process of change that affects the way we work and the way our institutions work. We have to define our roles as technicians, and also have our other skills taken seriously and take them seriously ourselves. The make-up and funding of institutions (especially the funding timetables of programmes designed to help resource-poor farmers) will have to change. But these changes have to start as personal changes especially in terms of how we relate to farmers. We must also accept and force our institutions to accept that if we are to participate with farmers this will require more from us: more time, more money, more inventiveness, more flexibility. New ways of bringing research and poor farmers together are needed and it is up to groups like this to have the vision to define what some of the new ways will be.

Dr Chambers has pointed out that there will always be a place for good scientific research and for good technical knowledge (page 11). Our job during this seminar is to define that place - this seems to be necessary because we are implying that our technical knowledge is no longer the driving force for changes in resource-poor farmers' methods. There is a tendency to bring research and farmers closer together and to improve the accountability and access in both directions. This process requires the kind of information that it is claimed can be obtained using participatory methods. We need not only to be more aware of the information that farmers have (the acceptance of indigenous technical knowledge), but also to be aware of their attitudes. We need this information even where the farmers are wrong or where we disagree with their approach. Even where the African farmer is wrong, she is right.

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DISCUSSION

N. D. Jago (*NRI, Chatham, UK*). I have to admit that our grain banks have been a failure under the very unstable conditions experienced during the five or six years of our programme in Mali. The principal value of the programme, according to farmers, was that our investment provided a way of releasing money slowly to them over a period: they were able to go to the grain bank and take grain when they needed it, which gave them additional time in the fields.

J. Rowley. I think the local availability of grain is perceived as one of the potential advantages of cereal banking, but there are no two cereal banks the same, and a large number often fail for a number of different reasons. Where they work, it is because this activity can be easily grafted onto a unit that already has some social cohesion. Learning to manage a cereal bank at the same time as learning to work together in some sort of social way imposes an almost impossible strain on people in a very difficult environment.

P. Nkunika (*Department of Biology, University of Zambia*). Please could you give us some more information about OXFAM? How widely distributed are your products in Africa? How do you interact with the other NGOs and donor agencies in Africa? What is the percentage of agricultural and crop protection programmes?

J. Rowley. Distribution of OXFAM products in Africa is patchy and covers about 27 countries, all south of the Sahara. The percentage of agricultural programmes is about 30%. We fund quite a lot of crop protection and have also funded emergency protection during grasshopper, locust and rat plagues. OXFAM funds village groups, local NGOs, northern NGOs and organizations such as the European Consortium of NGOs (ACORD).

OXFAM has its own funds and spends its own money as recommended by country representatives, so there is a huge range of different styles of project, either direct funding of village groups, funding of local NGOs, or funding through consortia. OXFAM takes 10% of its funds from the UK Overseas Development Administration and another 10% from the European Community, but there has been very limited collaboration with the others, such as UNICEF and UNDP - the styles of those organizations are so different that it makes collaboration very difficult.

T. Sengooba (*Namulonge Research Station, Kampala, Uganda*). At the moment the funding timetables that we have are three or five years, and we find that during that time vehicles may be bought and people trained, but at the end of the five years the vehicles will be old and the project will be coming to an end. The people who received money for training may just return at the stage when the project has to be wound up. Even if it is possible to negotiate a second phase, in many cases there is a lapsed period between the first and second phases. Funding timetables need to be reviewed. In the case of my government, for example, when a project is funded we also receive counterpart funds from the government, but once the external funds cease, the government also stops these counterpart funds.

Health considerations in crop protection for resource-poor farmers

R. T. DEANG

Fertilizer and Pesticide Authority, 6th Floor, Raha Sulayman Building, Benavidez Street, Makati, Metro Manila, Philippines

ABSTRACT

This paper presents the state of crop protection with the use of pesticides by resource-poor but market-oriented farmers in the Philippines. It also discusses farmers' perceptions on pesticide use, practices, use of personal protective measures, and incidence of illness associated with pesticide applications. Two global situations are identified: continued use, and minimal use of pesticides in agriculture. Approaches to safety in pesticide technology are also presented. Infrastructures and concepts include the FAO code of conduct on the distribution and use of pesticides; national regulatory authorities; personnel protective clothing and equipment (PPE); and IPM and sustainable agriculture (SA). A summary of the SA analytical concept is also incorporated. Noteworthy recommendations include: (i) campaigns are needed to encourage farmers to read the pesticide label and follow precautions and directions for use, (ii) PPE made of locally available materials should be developed, (iii) manufacturers should recall and dispose of out-of-date pesticides, (iv) the FAO code on pesticides and the prior informed consent protocols should be adopted, (v) research, training and education need to address farmers' circumstances, and (vi) donor countries of food aid should instead support food production in recipient countries.

RESUME

Cette communication traite de la protection des cultures, grâce à l'utilisation des pesticides, par les paysans des Philippines disposant de peu de ressources mais souhaitant vendre leurs produits sur le marché. Elle examine aussi les perceptions des paysans sur l'utilisation des pesticides, les pratiques agricoles, l'utilisation de mesures de protection et l'incidence des maladies associées à l'application de pesticides. On a identifié deux situations générales: une utilisation continue et une utilisation minime des pesticides en agriculture. Les manières d'aborder la question de la sécurité dans la technologie des pesticides sont également présentées. Les infrastructures et les concepts incluent le code de conduite de la FAO sur la distribution et l'utilisation des pesticides; les autorités nationales de réglementation; les vêtements et l'équipement de protection personnels (EPP); la lutte intégrée contre les fléaux (IPM) et une agriculture durable. Un résumé du concept analytique de l'agriculture durable est également inclus. Des recommandations dignes d'intérêt incluent: (i) la nécessité d'organiser des campagnes pour encourager les paysans à lire l'étiquette sur les pesticides et à suivre les précautions recommandées et le mode d'emploi, (ii) des vêtements et de l'équipement de protection à base de matériaux disponibles localement de vraient être conçus, (iii) les fabricants devraient récupérer et détruire les pesticides dont la date limite d'utilisation a expiré, (iv) le code de la FAO sur les pesticides et les protocoles ayant trait au consentement, reçu après information, devraient être adoptés, (v) la recherche, la formation et l'éducation devraient prendre en ligne de compte les circonstances propres aux paysans, et (vi) les pays donateurs d'aide alimentaire devraient plutôt apporter leur soutien à la production alimentaire dans les pays bénéficiaires.

INTRODUCTION

Farmers are in general reasonably good decision makers. As such, their views should be taken into consideration when changes are to be introduced, such as new production technologies with reasonable levels of risk, under a situation of limited resources. Farmers will tend to accept changes if they will lead to better production and if they are compatible with their existing farming systems.

Farmers' decisions on resource allocation and management strategies are influenced by both external and internal factors. External factors include (i) natural circumstances, e.g. weather, soil and topography, and biological factors like pests, diseases and weeds; (ii) economic circumstances, e.g. market opportunities, input distribution, credits, institutions and national policies; and (iii) social and cultural circumstances, e.g. land tenure, religion, and tribal norms. However, internal factors consist of family priorities and resources. These two types of factor, in interaction with a series of technical constraints, significantly affect productivity. Understanding farmers' circumstances and the effects of their economic decisions will enhance success in assisting them to increase their incomes through new crop production techniques.

The use of pesticide technology in agriculture has had both positive and negative consequences. In the Philippines, studies on pesticide use in rice showed favourable returns of investment. However, it was noted that widespread use of pesticides by rice farmers on small landholdings in Central Luzon, the heartland of the rice-growing area in the Philippines, resulted in a 27% increase in deaths in the area due to causes other than physical injury (Loevinsohn, 1987).

This paper seeks to assess the safety aspects of pesticide technology in resource-poor farming. It introduces approaches to safety in pesticide use in the context of the external and internal circumstances influencing the farmer's decision. It also deals with the farmer as the focus in the development of local specific technologies.

FARMERS' PERCEPTIONS ON PESTICIDE USE

Pesticide usage varies from none among subsistence farmers to significant in market-oriented farmers. Of the latter group, the degree of pesticide usage varies according to the value of the crop and the consumer's cosmetic preferences concerning agricultural produce. For instance, a survey conducted in 1987 among the vegetable growers in Benguet, a mountain province in the north of the Philippines, indicated that potato is popularly grown because of lesser risks in production and marketing spoilage, although other vegetables such as Chinese cabbage, lettuce, cabbage, carrots or peas produce higher profits (Rola, 1988). The preference of consumers for damage-free vegetables is reflected in the proportion of pesticide costs to the total variable cost, which is highest in cabbage (44%) and lettuce (38%) and lower in potato (27%) and peas (20%).

Use of pesticides with calendar-based spraying is prevalent; 88% of respondents stated that the use of pesticides has increased their production, and 98% agreed that a significant decrease in profit will most probably occur if pesticide use is discontinued. Most of the farmers do not know of any alternative pest control measures. Although 8.5% know of biological control methods, only 4.7% actually practise this for pest control (Rola, 1989).

When asked about the social impact of the use of pesticides, 98% of respondents were aware that pesticides are detrimental to public health, 93% claimed that pesticides polluted water, air and land, while 81% said they contributed to the decrease of wildlife populations. However, 99% would continue to use pesticides to protect their crops despite these impacts (Rola, 1989). This means that farmers consider that survival in their only means of livelihood is a higher consideration in relation to other factors, such as health and the environment.

USE OF PROTECTIVE MEASURES AND INCIDENCE OF PESTICIDE-ASSOCIATED ILLNESS

Based on the data presented in Rola's paper (1988), the following protective clothing and practices are used while spraying pesticides: 55% of respondents use masks, 26% wear gloves, 18% wear boots, 36% wear coats and 15% use eyeglasses. A handkerchief may be used as a mask to cover the nose and mouth. 67% of respondents practise spraying towards the wind, 22% spray against the wind, and 11% spray in both directions.

Records from the Lutheran Hospital (a private hospital) in Abatan, Benguet, showed lower incidence of illness among users of protective clothing than among non-users except those who wear masks (55%). The data showed that the protective clothing and equipment used by the local farmers are very inadequate in minimizing their exposure to pesticides. The most common route of exposure is inhalation and the most common symptoms are headaches/dizziness (53%) followed by chest pains/coughing (12%), eye and skin irritation (12%), stomach ache (12%) and vomiting (11%). A high incidence of pesticide exposure was observed among able-bodied workers who were actively involved in vegetable growing, although cases were also encountered among women, children and older folks. Indications of chronic effects of pesticides on the farmers were also observed (Rola, 1989).

APPROACHES TO SAFETY IN PESTICIDE TECHNOLOGY

Given these conditions, two significant global situations are identifiable - continued use and minimal use of pesticides in agriculture. In both situations, judicious and safe use are critical considerations.

Continued use in agriculture

Judicious, safe use of pesticides is institutionalized at both international and national levels by the Food and Agriculture Organization (FAO) and World Health Organization (WHO) of the United Nations, pesticide industry organizations and their company members, country pesticide regulatory authorities, and agricultural crop producers, among others.

The FAO International Code of Conduct on the Distribution and Use of Pesticides

The FAO Code addresses the numerous negative effects on public health and in the environment associated with pesticide usage. Although adoption by country is voluntary in nature, the code plays the role of 'enabling acts' in countries without pesticide regulatory infrastructures and registration systems. The code promotes "practices which encourage the safe and efficient use of pesticides, including minimizing adverse effects on humans and the environment and preventing accidental poisoning from improper handling" (FAO, 1986).

The code was revised in 1990 to include "Prior Informed Consent" which is the "procedure for formally obtaining and disseminating the decisions of importing countries as to whether they wish to receive future shipments of pesticides that have been banned or severely restricted" (FAO, 1990).

National regulatory authorities

Regulatory authorities have made a considerable contribution to safety. A study conducted by the Asian Development Bank on 15 countries in the Asia-Pacific Region showed that countries have pesticide registration schemes and control for imports, distribution, sale and use of pesticides. Burma, Nepal and Western Samoa have none, while Papua New Guinea is in the process of establishing a pesticide registration system. Bangladesh, Fiji, India, Indonesia, Malaysia, Pakistan, People's Republic of China, Philippines, Republic of Korea, Sri Lanka and Thailand have their respective enabling acts. However, enforcement of directions for pesticide use and farmers' training range from occasional to minimal, and monitoring of residues in food and the environment range from none (through occasional and minimal) to regular. With the problems of limited manpower and operating budget, regulatory restrictions and import controls appear to be the only significant actions available to prevent or minimize hazards from pesticide use (Asian Development Bank, 1987).

Personnel protective clothing and equipment

The use of personnel protective clothing and equipment (PPE) in the farmers' fields has significantly reduced pesticide hazards in developed countries. In the developing countries, especially those in the tropics, the PPE designed in the west is not adaptable to tropical farms. However, less efficient PPE and other safety measures have contributed to reducing exposure to pesticides.

Integrated approach towards minimal use of pesticides

Two significant approaches to crop protection are curently adopted in most countries world-wide. They are integrated pest management (IPM) and sustainable agriculture (SA). An element common to both is the combination of natural means of pest control, such as the use of resistant varieties, cultural practices, crop rotation, following multiple cropping including trap cropping, the use of biological control agents, and selective need-based use of pesticides. The components of the technology, people and environment vary in emphasis.

Integrated pest management

IPM is a dynamic technology that addreses site-specific social and economic questions. It is an integration of a number of control strategies and tactics. Monitoring of implementation must be carried out at all levels, and the benefits must be compatible with the farmers' system of values. As presently conceived, IPM focuses on developing farmers' capabilities to be good pest managers, with a good working knowledge of biology and economics. The concept has been simplified for easier adoption with the benefits compatible with the farmers' systems of values (UNEP, 1987; Gips, 1990).

In the Philippines, IPM was adopted by the Department of Agriculture in 1987 as a national pest control strategy, although the technology has been evolving in the country over the past 20 years. Technology verification in farmers' fields and training of agricultural technicians and farmers are key elements of the programme. While some progress has been made in rice and corn, much work is still needed on extension, adoption, mass rearing of *Trichogramma* parasites, developmental work on other crops, and geographical specificity.

Successful IPM of cassava mealybug (*Phenacoccus manihoti*) has been demonstrated in seven African countries. Aerial and ground releases of the parasitic wasp *Epidinocarsis lopezi* (Enclytidae) from 1981-85 showed successful establishment and continued spread of the wasp from the release site into neighbouring countries (see page 45); its presence in 11 African countries was noted by the end of 1985. *E. lopezi* was introduced from the Paraguay-Bolivia-Brazil area and was tested in Ibadan, Nigeria, for effectiveness by the scientists of the International Institute for Tropical Agriculture (IITA). Although *E. lopezi* covers a little more than 12% of the area of mealybug infestation, continued search, study and release of other species of natural enemies are ongoing activities.

The cotton boll weevil suppression programe of the new Government of National Reconstruction in Nicaragua met with some success in 1984. Started in 1982, the IPM component explored was trap cropping. The practice consists of planting pre- and post-harvest trap crops of cotton on specific dates, treating the post-harvest trap crops with a boll weevil pheromone, and subsequently spraying the trap crops with methyl parathion to kill the weevils. The total volume of pesticide used on the trap crops was reduced by half, as compared with the regular spraying programme in cotton growing. The total saving from insecticide for the entire test programme was 29.3 million cordobas and an average profit of 365 cordobas/ha was achieved (Hansen, 1987).

Sustainable agriculture

As environmental and health hazards mount as a result of heavy pesticide usage, leading to deterioration in rural economies, a new holistic perspective emerges in food production - sustainable agriculture. This is a dynamically evolving system in which widely divergent agricultural practices and conditions are evaluated, modified and verified in order to create a productive and continuing sustainable agriculture. The concept is environmentally oriented, although people and technology are also given significant weight.

The system utilizes components of related disciplines and concepts such as IPM, farming systems approaches in production, research and extension, agroforestry and agroecology (Dar, 1990; Gips, 1990). Because of the diversity of approaches, sustainable agriculture is often referred to as an organic, ecological, resource-efficient, low-resource, natural, biological or regenerative system. This system does not exclude chemical inputs, but seeks to reduce such inputs in order to contain both the environmental impact and the costs.

SUMMARY

Based on examination of the circumstances surrounding resource-poor farming and the various alternatives available, we look at a new farming system focused on the interaction of people, technology and environment. Firstly, we need to pin our orientation on people, because generation of productive technology and protecting the environment are human acts. We need to look at agriculture as a community activity, where organizational structure and traditions affect management decisions. We must assess existing resources and how they are managed in relation to the farmers' values, norms and attitudes. What improvements in the areas of technology, services, skills and organization can we devise to make farm management efficient and effective? Are these innovations environmentally friendly? Will they optimize production? We have to develop the appropriate structures to create a new sense of identity among farmers - that of efficient and effective farm entrepreneurs.

While the use of pesticides will remain as a component of crop protection, the campaign for judicious and safe use must be enhanced. This must be accompanied by responsible product supervision by the pesticide manufacturers. The government and the private sector must work together in delivering safety information to the often forgotten resource-poor farmers.

RECOMMENDATIONS

* Judicious and safe use of pesticides through careful reading of the label and following of directions in usage, and use of locally designed, efficient protective clothing and equipment must be promoted.

* Stockpiles of out-of-date pesticides in developing countries should be recalled by the pesticide manufacturers involved and disposed of properly.

* Countries exporting dangerous and/or restricted pesticides should adopt the FAO/UNEP Prior Informed Consent protocols whereby importing countries are provided with information on the dangers and hazards of pesticides before they are imported.

* Research for viable technology, training and education should be site-specific, community relevant and appropriate to farmers' circumstances. Researchers must be geared to an agricultural production system that promotes health, economic production and environmental protection.

* Inappropriate agricultural, economic and trade policies of industrialized countries are obstacles to sustainable agriculture which have trapped both their farmers and those of the developing countries, eroding the resource base on which food production depends. International organizations, for instance on food aid, should instead shift the emphasis to the production of food commodities by the resource-poor farmers in food deficit countries.

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DISCUSSION

J. C. Reid (*CARDI, Kingston, Jamaica*). What is your experience of the social patterns in farmers' use of pesticides, particularly in matters such as storage and disposal, where there needs to be some focus in education? Also, concerning your idealistic list of recommendations, what is your feeling as to how many of these are actually adopted, in the Philippines or elsewhere?

R. T. Deang. In the Philippines we have an extensive training programme, through which we address pesticide dealers on the handling and storing of pesticides, and on what information to pass on to farmers. It also addresses the medical professions, giving information on the recognition and management of pesticide poisoning. On the farmer level, the authority passes information to the field men of the Department of Agriculture because they are the ones that meet the farmers most of the time. We have 400+ registered formulated products, and among these are a number of toxic pesticides in categories 1A and 1B of the World Health Organization's Classification of Pesticides by Hazards. At present we are reviewing the registration of all these toxic formulations. We provide a training module which includes transporting, using, handling, etc. We also have a package module for pest control operators, which consists of a three to four-day seminar leading to certification.

W. N. O. Hammond (*IITA Biological Control Centre for Africa, Cotonou, Benin*). I would like to know whether the legislation you have for the use of protective clothing is voluntary? Also, for the highly toxic pesticides in Group 1, are there any restrictions for the resource-poor, semi-literate farmers - are these chemicals easily accessible to them, or do you control the distribution?

R. T. Deang. Pesticides are registered and classified into banned, restricted or general-use pesticides. General-use pesticides are available throughout the country, but restricted pesticides are only allowed to be bought by certified pesticide applicators and are kept away from the general public. Of course, misuse is always a big problem. For instance, in some places aldrin is still used as a post-harvest treatment for vegetables. We have tried monitoring the area, and carrying out an educational campaign, but clandestine use still continues, so aldrin is now banned. If we cannot handle things through training or educational campaigns, we still have the authority to cancel registration of the pesticide. Use of protective clothing for workers is legislated in manufacturing, formulation and repacking plants, and advice is given to farmers.

E. A. Babiker (*Ministry of Agriculture, Animal and Natural Resources, Khartoum, Sudan*). Are your health figures with respect to poor farmers based on chronic toxicity or on acute toxicity? In Sudan, DDT has been found in mothers' milk - can you indicate whether similar hazards have occurred in the Philippines?

R. T. Deang. We have restricted DDT since 1981 and have also found that DDT is found in mothers' milk. The only use of DDT now in the Philippines is for malaria control, it is banned for agricultural use. However, at this stage the Department of Health is looking for alternatives to DDT, because it is stable in the environment.

Summary and key points for discussion groups

G. KIBATA

National Agricultural Laboratories, Nairobi, Kenya

The resource-poor farmer, our target this week, has an extensive knowledge base accumulated from his/her own experience. It is not that farmers do not know what to do, but that they are not particularly familiar with our scientific training. Similarly, we cannot claim at the moment that we are trained to address ourselves to resource-poor farmers - and our lack of training may be our biggest handicap. It has been noted that only about 20% of technology is transferred to resource-poor farmers. Why? Is it because we do not have the knowledge base appropriate to the farmer? We went on to talk about the desirability of IPM as possibly providing a cheaper way of approaching farmers' plant protection problems. However IPM, though it may be good for the resource-poor farmer, is not always cheap. It may not even result in a reduction in the use of pesticides. Farmers are often looking for a way of increasing their use of pesticides, but it has also been pointed out that we must use these resources carefully, protect our environment and protect our health. Pesticides may be mismanaged within the resource-poor community, and restrictions are often the only way to safe management.

Scientists' criteria for judging 'success' may be very different from farmers' criteria. Increased productivity may not be the only criterion for success - the farmer may have his/her own concept of what is a success, for example when the crop has survived a drought and the farmer has something to harvest - it might be a very poor breed genetically but at least it survives the drought.

We have discussed the complex, diverse response systems of resource-poor farmers in comparison with industrial and green-revolution agricultures. However, scientists must face the challenge to be much more broadly based in their approach and look at the farmers' needs, not only the crop (which might be the central theme to agronomists or crop protection officers), but also livestock, fisheries, and many other factors that constitute a farmer's economic system. So while we might have some comparative advantage concerning issues that we know about, the farmer knows something else. When we are considering this ranking system we must, as the socio-economists normally imply, be able to segregate the resource-poor farmers' concepts and understanding, including what may be distinct male and female criteria for what is successful.

The questions that arise are: Whose knowledge counts? Who chooses? Who gains? Possibly what is most important is the ability to educate the farmer to appreciate hidden crop losses and the diseases that farmers do not recognize, and also to be able to assist the farmer in the community, to forecast the weather and to make other inputs that are beyond his/her knowledge. For example, in Malawi pesticides are used extensively, but with a forecasting system that helps the farmer to know when intervention is necessary. It is the management of pesticides that is actually being guided by scientists.

We have also been given examples of successes in biological control - the cassava mealybug and the cassava green mite. We have also been promised that biotechnology has something to offer the resource-poor farmer - this is an area that is growing and expanding, and might offer the kind of strong and sustainable inputs that the resource-poor farmer requires. There is also one challenge that came out very strongly from Professor Buddenhagen's address - that plant breeding is the most likely and most important sustainable approach to the problems of resource-poor farming. Plant protection is not the only route: an alternative may be improved seed, or suitable material that is able to survive within the context of the complex system of resource-poor farming.

One other aspect is that of disciplinary approaches. We need to get away from our own disciplines and training, and think about where the resource-poor farmer might gain the most from our knowledge. We have actually been talking about small-scale farmers, but I think we have not been addressing ourselves to the poorest of the poor and, at this stage, we need to define what we mean by resource-poor farmers. What are the farmer's constraints? As I mentioned above, IPM is possibly not the cheapest of available strategies because it may mean increased use of resources. The limiting constraint in the Sahel region and in many areas where resource-poor farmers are found is not just land: good land might be a limiting factor; water might be a limiting factor; but the farmer's resource-poor state is due to many more factors than land. Technology is also an important limiting factor - the farmer has some knowledge but may need more information, which we might not even have. International intervention may be very important. Economics is also a problem, as prices are beyond the farmers' control. The crucial question is whether the resource-poor farmer is able to feed him/herself and family - that is about as far as we can go. The small-scale farmer is not necessarily the most resource-poor farmer. We also need to address ourselves to whether there are any suitable technologies available for farmers who are living on the verge of starvation, in such poverty that they are doomed not to survive.

DISCUSSION

S. M'Boob (*FAO Regional Office for Africa, Accra, Ghana*). I am in agreement with most of the things you have said, but I do have a problem with your concept of IPM. You say IPM can mean the use of more pesticides but in my view this cannot be IPM - the central theme of IPM is to reduce the use of pesticides. IPM has been defined by FAO as a reduction in the use of pesticides. One reason for problems with IPM projects in the past has been that we have focused our attention on crops that did not have problems with pesticides. There is no point trying to develop IPM technologies for crops that do not have a pesticide problem. The FAO panel of experts on IPM has recommended that in the future efforts to develop IPM techniques should focus on crops that have a pesticide problem, or risk having a pesticide problem. IPM is defined as what is considered the best mix by the farmer, so IPM cannot be more expensive for the farmer as he would not consider that the best mix.

R. W. Gibson (*NRI, Chatham, UK*). Definitions of IPM were not intended to be central to this meeting: what we want to focus on is protecting the crops of resource-poor farmers. As far as this meeting is concerned I am not sure we need to define IPM.

R. T. Deang (*Fertilizer and Pesticide Authority, Metro Manila, Philippines*). The question is not what we would ideally like IPM to be but what actually results - I would agree that IPM has in some cases increased the use of pesticides in the Philippines and elsewhere. We cannot ignore that situation just because it does not fit in with our concept.

W. N. O. Hammond (*IITA Biological Control Centre for Africa, Cotonou, Republic of Benin*). There is confusion about the use of 'IPM', which can in some circumstances be seen as an alibi to use pesticides - but the African poor farmer is in a specific situation. For example farmers growing cassava, which is intercropped with many other crops, do not even think about applying pesticides. We should not try to impose IPM technology in a situation where it is not necessary. We need to look at the problems within the system and how to go about solving those problems.

Key objectives and recommendations

INTRODUCTION

An objective of this seminar was to provide a forum to examine and evaluate the various approaches to pest control as they pertain to the circumstances of resource-poor farmers, with the aim of identifying the approaches most likely to be of benefit. For a more detailed examination of the issues involved, the delegates chose to split into three groups to consider the topic from the viewpoints of (i) resource-poor farmers, (ii) scientists/leaders of research groups, and (iii) policy-makers such as government ministers or donors.

To provide structure to the discussions and to allow comparisons to be made between the conclusions of the groups, each was asked to consider and prioritize (i) the techniques resource-poor farmers should use, (ii) how these techniques can best be developed, and (iii) how the recommended changes should be achieved. The 'resource-poor farmer' and the 'scientist' groups structured their considerations in a similar manner, looking at what is essentially the same problem, but from different viewpoints. The comparisons drawn are sometimes thought-provoking. The 'policy-maker' group necessarily had a broader perspective, looking at the same problem but being responsible for both scientists (as employees) and resource-poor farmers (as citizens).

GROUP I - OBJECTIVES AND ACTION POINTS FROM THE VIEWPOINT OF RESOURCE-POOR FARMERS

Target group

A resource-poor farmer may be constrained by one or a combination of the following:

* limited land availability and quality
* limited labour (often has to depend on family labour)
* limited marketing facilities
* limited access to production and marketing information
* limited financial resources, e.g. credit
* unfavourable climatic conditions.

Objectives

The resource-poor farmer wants to be self-sufficient in food production in order for his/her family to survive, to sustain and improve their standard of living.

GROUP II - OBJECTIVES AND ACTION POINTS FROM THE VIEWPOINT OF SCIENTISTS / RESEARCH INSTITUTES

Target group

To avoid the 'politics' of defining who is a resource-poor farmer, we regard a resource-poor farmer as one constrained by any of the following, individually or in combination:

Capital	cost, money, inputs, physical facilities, etc.
Land	site and/or quality
Labour	availability/financial capacity to accessible labour
Technology	quality of existing/lack of new technology
Knowledge	existing indigenous body of knowledge/new generation of knowledge
Infrastructure	roads/water resources
Environment	situation-specific characteristics (e.g. semi-arid, arid, forest zones, etc.)
Traditions	(social)

Objectives

Immediate: To protect food crops (subsistence/market) from pests by provision of appropriate technologies. Technologies which are practically feasible/relevant to the situation, easily adoptable within the existing infrastructure and financial capacity, and are sustainable.

Long-term: To improve the quality of life. Improved quality is relative, depending on the disciplines of scientists and politicians.

Resource-poor farming systems: constraints on achieving objectives

* Land availability and security (land tenure system)

* Credit facilities (problems and advantages)

* Marketing (availability of proper markets and prices)

* Infrastructure (roads, irrigation facilities etc.)

* Alternatives to agricultural production, e.g. fishing, hunting, backyard small industries

* Appropriate technology

  acceptability (farmer preferences)

  yield security (sustainable)

  marketability

  storability

  resistance or tolerance to major pests

* Farmer-scientist interaction. Respectful and healthy interaction between the two partners should exist.

* Values for local and traditional cultivars and production methods. When introducing new varieties and production technologies, the scientists should not advise farmers to abandon or neglect local cultivars and production methods.

* Involvement of farmers in technology development and improvement. Involve farmers as much as possible particularly at:

  (i) identification of production constraints,

  (ii) evaluation of technology.

  This can be done at a strategic stage during the development process in order to assist the scientist to achieve the required results.

Resource-poor farming systems: constraints on achieving objectives

The identification of constraints in achieving the objectives is to be undertaken by both farmer and scientist with some assistance from the extension agencies. Possible problems cover a wide range of factors, e.g. social, biological, environmental.

Social:	Traditions/culture Myths (taboos) Religion Political
Biological:	Pest systems (are dynamic and need constant review) Existing farm systems Soils
Environmental:	Climatic Topography Water source Accessibility to others

Though our mandate is to offer/provide appropriate crop protection options, the above factors must be considered in a matrix. An inventory should be made of existing crop protection practices to discover what the farmer does to control the pest problem by interviews, discussions, indirect prompting, etc., with the farmer playing the key role. An appraisal of the practices which exist at local, national and international levels is needed. Through this appraisal, prioritization of the various crop protection options for each pest group will be done using criteria such as cash, labour, safety, and rate of uptake by the farmer.

Pest	Control options	Ranking
Indigenous	Indigenous practices	1
	Biocontrol	1
	Local quarantine	2
	Resistant crops	3
	Cultural practices	3
	Pesticides	4
Exotic	Quarantine	1
	Biocontrol	2
	Cultural	3
	Pesticides	4
	Resistant crops	5
Migratory	Legislative	1
	Pesticides	2
	Biocontrol	3
	Physio-mechanical	4

Score = 1-5, 5 = least favoured

* Information exchange. Farmers' knowledge should be the starting point for any technology development. There are various ways and means of information exchange, e.g. news media, on-farm demonstrations, farmers' days, etc., but this must be a two-way exchange.

Recommendations

Resource-poor farmers require that inputs for crop protection are minimal; common practices include: (i) host-plant resistance to pests, adaptable crop plants (hardy crops) and (ii) pesticides (conventional pesticides and biocontrol agents). Desirable features include:

* cheap, effective, least toxic available

* adequate information (including any alternatives)

* proper registration system

* application technology should be durable, economic and easy to use

* availability of after-sales supportive services for spraying equipment

* spraying instructions should be simple, clear and practical (this includes sprayer calibration instructions)

* information on post-harvest residual effects should be provided

* provide simple and clear instructions on how to handle pesticides and poisoning cases (first aid measures at farm level)

* as farmers, we should be self-conscious and value our traditional pest control methods, food processing and preservation.

Problems will be encountered either individually or in combination, so a matrix of options may need to be considered. After the appraisal, relevant farmer-led co-operative research is to be undertaken to determine the effectiveness of the various crop protection options for each specific situation. Simultaneously, parallel research could be carried out at national research institutes for verification and/or to find possible gaps which might be overlooked. The results of this research will then be evaluated by both farmers and scientists and recommendations will be issued to the relevant parties. At this stage the farmer will have a chance to see the 'fruits' of joint efforts. Having 'jointly' developed the appropriate situation-specific technology(ies), the next requirement is the transfer of technologies to wider groups of farmers by training extension staff and offering demonstrations/training of farmers.

Recommendations

* minimal use of pesticides, cheap equipment, back-up service for crop protection equipment

* registration of pesticides, small first aid kits

* indigenous crop protection practices, food preservation methodologies and inventory of these)

* training in crop protection (and in agriculture in general)

* extension system must be reliable - so far is not efficient

* information to reach the farmers.

Diagnosis: Farmers need training to be able to carry out proper identification and management of pests and beneficial organisms.

Extension system: There is a need for an effective and reliable extension system. The extension staff should be well trained and effective in plant protection methods.

Gender: Crop production is mostly done by women and children, but information is often passed to the head of the family (often a man), so information does not always reach the end user properly. Because of varied cultural norms and customs, scientists should take this into consideration when dealing with farmers. The appropriate approach to reach the target group (end users) should be used, e.g. women's groups, religious groups, etc.

Action

* To facilitate information exchange and possibly technology transfer and development, farmers should organize themselves into co-operative or working groups.

* Policy-makers should give priority to agricultural development projects.

* Farmers should be involved in policy-making through community groups.

GROUP II: **Glossary**

Scientists: all scientists associated with agriculture, particularly with crop protection, including entomologists, pathologists, weed specialists, nematologists, epidemiologists, socio-economists, biometricians, soil scientists, anthropologists, etc.

Pests: all biotic factors harmful to various crop cultures, e.g. insect pests, phytopathological agents (fungi, bacteria, viruses, nematodes, fastidious organisms, rodents, birds, parasitic plants and in some instances *Homo sapiens*).

Pesticides: proprietary or synthetic based on natural plant sources, excluding the new generation of biotechnological products (e.g. fungal, bacterial (including *Bacillus thuringiensis*) and viral formulations).

Biocontrol: use of predators, parasitoids or biological products excluded under pesticides.

Cultural methods: all practices in farm operations including: time of planting, depth of seeding, removal/destruction of crop residues, inter/mixed cropping, trap plants, etc.

GROUP III: OBJECTIVES AND ACTION POINTS FROM THE VIEWPOINT OF THE POLICY-MAKERS

Objectives

* To review policy for increasing crop production by resource-poor farmers through cost-effective, safe and sustainable crop protection methods.

* To develop action plans for implementation of revised policy.

Step 1

The following aspects of the circumstances of resource-poor farmers were identified as paramount in crop protection:

* crop profitability (market/price/yield)
* pests (local, migratory)
* socio-economic
* crop losses.

Recommendations: Farmer participation is needed in identification of key issues.

Step 2

Evaluation of existing farmers' crop protection practices, perceptions and knowledge.

Recommendations: Emphasize indigenous knowledge and plant protection methods.

Step 3

Review of relevance and capability of existing institutions to meet resource-poor farmers' needs (perceived and real) for:

* research
* extension/training
* farmer organization and empowerment
* legislation
* gender priorities.

Recommendations: Ensure farmers' identified needs are top priority through independent review.

Step 4

Re-define crop protection policy within national development plan.

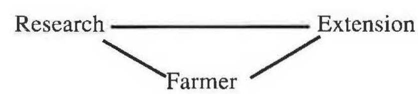
Recommendations:

Topic	Priority
Crop type	Subsistence food crops
Pest type	Sedentary
Crop protection	IPM
Inputs	Quality seeds
Incentives, subsidies (hidden/visible)	Fair producer price, market price for pesticides
Farmer organization	Promote
International co-operation	Appropriate technology transfer

Step 5

Define requirements to implement new crop protection policy.

Recommendations: Manpower capabilities
Infrastructure
Finance
Linkages



Step 6

Compare requirements with available resources:

* government
* international (including CGIAR centres)
* private sector, NGOs.

Recommendations: Round table with governments, international donor groups, private sector groups, non-government organizations to promote beneficial collaboration.

Step 7

* Re-allocation of resources.
* New budget preparation.

Recommendations: Strictly follow priorities of new crop protection policy.

Step 8

Implementation: programme formulation
execution
monitoring
evaluation.

Recommendations: Continuous farmer participation at all stages.

Concluding remarks

A. C. JACKSON

CTA, Postbus 380, 6700 AJ Wageningen, The Netherlands

The primary objective of CTA in holding meetings of this kind is to help participants from the African, Caribbean and Pacific countries, and those at home unable to attend, to be more effective in carrying out their duties and responsibilities now and in the future. Robert Chambers has pointed out how our formal education can become a handicap in circumstances where technology is changing rapidly, and we believe that this problem can be addressed through meetings of this kind.

The specific objectives of this meeting were to provide a forum to examine and evaluate approaches to pest control, ranging from traditional practices to western high-technology approaches; to consider the relevance and usefulness of the latter to resource-poor farmers; to identify which of the modern and traditional technologies are most likely to benefit farmers in ACP countries; and finally to find means of promoting them, to propose practical measures to ensure that the desirable technical trends that we identify are promoted in ACP countries. I would highlight the three questions Robert Chambers has posed: Whose knowledge counts? Who chooses? Who gains?

It has been said that, at present, the developing world finds itself in a hybrid era unlike any other period of history. In addition to artisans and engineers, farmers and visionaries, the direction of technology is nowadays being influenced and fashioned by bureaucrats, economists, far-away corporate planners, aid agencies and charities. Never before in history have so many non-technical people exerted so much influence on the advancement, retardation and movement of technology, and the consequences will be far-reaching. For us, this means that we must relay the messages coming from this meeting to a particularly diverse audience.

I would like to borrow a recent remark from Britain's Foreign Secretary made in a different context: he pointed out that it is no good shaking hands and agreeing at meetings, if afterwards you have to shake heads because your recommendations are ignored. A number of people have asked how we aim to project the findings, observations, conclusions and recommendations of this meeting out into the world. As far as CTA is concerned, this meeting is part of a continuum of discussion on the topic, not the first or last word - it shapes the way opinion is formed. From our point of view, it will affect what themes we will support in future meetings in this area, it will affect what meetings organized by other people we will agree to support, it will affect our choice of the kind of material and the emphasis of articles in publications like *Spore*, and it will have an effect on what books we choose to publish. It has an effect, in a small way, on what might be called the global opinion-making process. But I think it is important to see it as a component of that process, rather than as a one-off event. Our hope is that all the participants will see themselves as ambassadors for the issues raised by this meeting on their return home.

ABSTRACTS OF A POSTER SESSION ON CROP PROTECTION FOR RESOURCE-POOR FARMERS*

Natural Resources Institute, Chatham, Kent, 6 November 1991

Groundnut resistance to *Aphis craccivora*

F. KIMMINS, D. E. PADGHAM, R. J. GRAYER[+] and E. A. BARNETT

[+]*University of Reading, Department of Plant Sciences, Whiteknights, Reading, UK*

Groundnuts (*Arachis hypogaea*) are a prominent source of dietary protein and lipid, and are a cash crop throughout much of southern Asia and sub-Sahelian Africa. Virus infections transmitted by *Aphis craccivora* can be a major constraint to production. This aphid is the vector of the groundnut rosette assistor virus, and resistance to this insect has been identified in the groundnut cultivar EC 36892. Field and laboratory studies showed that this resistance takes effect only after the insect has probed the plant for 2 hours. Electrical studies of probe penetration indicated that location of the feeding site, the phloem, is almost as successful in the resistant EC 36892 as in the susceptible cultivar TMV2, but the mean feeding duration on the resistant cultivar was only half that on the susceptible cultivar. Chemical analysis indicates that high concentrations of the condensed tannin, procyanidin, are found in the petioles of cultivars which offer aphid resistance. When procyanidin was incorporated into artificial diets, apterous aphids survived on the control diet and one containing 0.0025% procyanidin for similar periods, but significantly less honeydew was produced. Higher concentrations in the diet resulted in greater mortality. This work indicates that procyanidin may be used as a marker for aphid resistance in groundnuts and could be used to enhance screening procedures.

Groundnut resistance to *Spodoptera litura*

P. C. STEVENSON

The larvae of *Spodoptera litura* are major defoliators of groundnuts (*Arachis hypogaea*), particularly in India. Crop damage from heavy outbreaks is responsible for significant yield losses. Although some groundnut cultivars have shown a degree of tolerance to *S. litura*, this is not attributable to an active resistance mechanism. However, field and laboratory studies at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) have identified several wild species of *Arachis* which increase larval mortality and inhibit larval development. One of the most resistant species is *Arachis paraguariensis*. The mortality of 1st instars on this species was 70% higher than that on the susceptible control *A. hypogaea* TMV2. Third-stadium larvae lost weight when presented with the leaves of *A. paraguariensis*, whereas those presented with leaves of the control cultivar gained weight by 50%. Larval development on 50% methanol extracts of the foliage of *A. paraguariensis* was severely inhibited in comparison with the foliar extract of the susceptible cultivar *A. hypogaea* TMV2. Chromatographic analysis of the active extract revealed three phenolic compounds present in the leaves of *A. paraguariensis* which were absent from the leaves of *A. hypogaea* TMV2. These compounds were isolated by semi-preparative HPLC and were incorporated into separate artificial diets at their foliar concentrations. All three compounds severely impeded larval development. After 14 days, larvae on the control diet were in the 6th stadium and weighed 900 mg, whereas larvae feeding on two of the isolated compounds weighed less than 5 mg and remained in the 2nd stadium. Larvae feeding on diets incorporating the third isolated compound had a mean weight of *ca.* 100 mg and were between the 3rd and 4th stadia. The chemical structures of these compounds have not yet been fully determined. However, they may provide valuable genetic markers for early selection in breeding and biotechnology programmes which would be required to transfer the resistance character from the wild to the cultivated species.

*Unless otherwise indicated, posters were presented by staff of the Natural Resources Institute, Central Avenue, Chatham Maritime, Kent ME4 4TB, UK.

Insecticide resistance in *Helicoverpa armigera* in southern India

N. J. ARMES, G. BOND and A. B. S. KING

Helicoverpa armigera has emerged in recent years as the dominant agricultural pest in India, seriously affecting some 20 million ha of pulses and 8 million ha of cotton, causing overall economic losses of over £160 million per year. Cotton crop failures during 1987 in eastern Andhra Pradesh were largely the result of *Helicoverpa* resistance to synthetic pyrethroids which have been in continuous use in the state since 1980. In 1983 some 480 000 litres were used on about half a million ha of cotton. *Helicoverpa* has also been shown to be resistant to DDT and to have low levels of resistance to endosulfan, quinalphos and methomyl. *Helicoverpa* is a major problem on pigeon pea, where losses of up to 80% are not uncommon, and is also important on tomato, sunflower and, recently, groundnut. Insecticides are sparingly used on these crops which are mostly grown by subsistence farmers. Since 1987, pyrethroid-resistant *Helicoverpa* in south India has been increasingly found attacking food crops distant from source areas on cotton, and has spread, or developed independently, on cotton in Tamil Nadu further to the south. Current work by NRI, in collaboration with ICRISAT and some Indian institutes, is focused on monitoring resistance in Andhra Pradesh and neighbouring states by widespread sampling from major crop hosts and giving assistance and training in bioassay work. The final objective is to develop a locally workable resistance management strategy.

Dynamics of pyrethroid resistance

Pyrethroid resistance levels from pigeon pea and chickpea at ICRISAT, near Hyderabad, increased from zero in July 1986 to 125-fold in November 1987. In subsequent years levels have varied considerably and tended to follow those in cotton, some 250 km to the east-south-east in Andhra Pradesh. Resistance in *Helicoverpa* from pigeon pea at ICRISAT increased from 81-fold in early October to 958-fold in mid-November 1989. Significant heterogeneity of the latter indicates segregation of resistant and susceptible phenotypes, supporting evidence for an influx of resistant moths. Studies of *Helicoverpa* movement suggest that there is considerable gene flow between populations. There is evidence for a north-westerly displacement of resistant moths from the cotton-growing region during October and November. Laboratory studies of flight have shown that moths are capable of covering 250 km in one night with the assistance of a moderate wind. During the Kharif (July-October) season the resistant population would have been diluted by susceptible immigrants from unsprayed crops and wild hosts. Selection for individuals carrying the genes responsible for pyrethroid resistance would occur once crop spraying started, with the frequency of resistant phenotypes increasing rapidly as the season progressed.

The use of rainfall as a predictor of egg laying by *Helicoverpa armigera* in the Sudan Gezira

A. D. MADDEN, M. HAGGIS and J. HOLT

Helicoverpa armigera causes considerable damage to cotton, a major cash crop in the Gezira irrigation scheme in Sudan. Control is undertaken when weekly sample counts exceed 10 bollworms (eggs + larvae) per 100 cotton plants. Ninety five percent of *H. armigera* egg laying takes place between September and early November when the cotton is early in its fruiting stage and consequently at its most vulnerable. Analyses of egg counts and rainfall data from 1973 and 1975 reveal some significant associations. Rainfall variables considered included: number of days (out of previous six) on which rain was recorded; number of days since last rainfall; distance from most recent rain; total rainfall in the six days prior to the count.

There is clearly some variation from year to year in the degree to which rainfall affects egg-laying. The number of days on which rain fell was the only variable significant for both years (Table 1). If further work confirms the relationship it may be possible to estimate the probability of an above-threshold count following a given combination of rain events. These probabilities could be of value when assigning resources for scouting.

Table 1 Percentage of egg counts greater than the economic threshold, following given number of days on which rain fell (expected value in each case was 28%)

No. of rain days	0	1	2	3	4
Percentage counts above threshold	10	13	23	47	46

Termite control - a dilemma for the small-scale farmer

J. LOGAN

Termites are major pests of agriculture, forestry and buildings in the tropics. Losses in crops and trees due to termites are often over 15% and can reach 100%. Traditionally built houses and grain stores can be destroyed in 3-9 years. High demand for timber necessitates the planting of fast-growing trees such as *Eucalyptus* which are especially prone to termite attack. Current major areas of research include the identification and taxonomy of species responsible for damage; ecological and behavioural studies; and research into control methods. With the discontinuation of persistent organochlorines, it is necessary to find a low-cost, safer but equally effective alternative. Chemical control methods studied have included the incorporation of less persistent insecticides into an inert matrix designed to release insecticides into the soil at known rates over a fixed time period. Also, non-repellent, delayed-action termiticides can be incorporated into baits. When eaten these act directly on the termite itself, or interfere with cellulose breakdown by killing the protozoa or the fungus comb on which they depend. Alternatives to chemical control include plant resistance; physical barriers such as the use of abrasive materials or metal shields to prevent termite contact with wooden structures; and biological control with pathogenic nematodes, fungi, bacteria, insect growth regulators and plant extracts.

Soil pests of crops in southern Malawi

A multidisciplinary team from NRI, Chancellor College (University of Malawi), Reading University and Imperial College (University of London) is assessing the impact of soil insects, weeds, pathogens and nematodes on the crops of subsistence farmers in southern Malawi. Important pests include termites, the weevil *Cylas puncticollis* which causes heavy losses in sweet potato, nematodes such as *Meloidogyne javanica*, and the parasitic witchweed *Striga asiatica*, which can greatly reduce yields of maize and sorghum. The interactions between the pests and local agricultural practices are being investigated with the objective of developing solutions appropriate to small-scale farmers.

Mali millet pest control - Sahelian IPM at farmer level

The project (1985-91) is located in north-west Mali near to the Mauritania/Mali border. NRI/ODA responded to a request from the Mali government to investigate means of protecting rainfed millet and sorghum against pest attack, particularly that caused by grasshoppers. The area chosen receives 300-500 mm rainfall per year. Millet is subject to a range of pests - the predominant insect pests, in order of importance, are listed below (years indicate when pests were causing major damage):

* grasshoppers (eight species) 1985, 1986, 1989
* millet candle miner (*Heliocheilus albipunctella*) 1985-88
* millet stem borer (*Coniesta ignefusalis*) 1990
* meloid beetles (three species of *Psalydolytta*) 1990
* cetoniine flower beetles (*Pachnoda interrupta*) 1989.

A 'menu' of recommendations has been formulated (see page 30).

Integrated pest management strategies to control the larger grain borer (*Prostephanus truncatus*)

R. HODGES

The larger grain borer (LGB) is indigenous to Meso-america but was accidentally introduced into East Africa (Tanzania) and West Africa (Togo) from where it is now spreading within the continent. The pest is highly destructive of farm-stored maize and cassava. In Africa, it has increased losses of farm-stored maize from less than 5% to approximately 10% per year. Losses in cassava are probably even higher. In Tanzania, the emergency control programme co-ordinated by FAO was successful in reducing local losses to stored maize. This was achieved by reliance on imported, synthetic insecticides. While the use of contact insecticides is clearly effective against LGB, long-term control of this pest would require a massive expansion in insecticide usage among rural African communities. For financial and environmental reasons, this is an undesirable prospect.

NRI is currently managing a project for the UK Overseas Development Administration to develop an integrated approach to LGB control within the framework of improved maize and cassava storage in Africa. These improvements will derive from basic research findings in Mexico, Togo and Kenya. In addition, the adaptive research and development programme undertaken in each of three regions has been designed to make specific and appropriate contributions to the national capability in the field of post-harvest crop protection.

Radar studies of brown planthopper migration

Biogeography and Radar Entomology Resource Centre

High-frequency radar was used to observe directly the long-range migratory flight of the brown planthopper (*Nilaparvata lugens*) in China. Quantitative data were obtained on the timing, altitude, direction, intensity and probable range of migration. The specially designed Q-band radar was able to detect the tiny individual planthoppers over all their flight heights. The identity of insects on the radar was confirmed by sampling with a net suspended from a tethered balloon.

Most migrant brown planthoppers took off between late afternoon and dusk, although there was a second period of mass take-off at dawn. They climbed to heights of several hundred metres and were displaced downwind. Later in the evening, vast numbers of migrating brown planthoppers often overflew the radar site in a dense layer with a distinct upper boundary corresponding to an air temperature of about 16°C. The data obtained can now be incorporated into population dynamics and forecasting models to improve the management of this pest.

Migration studies in IPM: studies of insect migration using trajectory analysis

L. J. ROSENBERG

Several major insect pests are known to migrate seasonally over long distances. Once airborne, such migrants tend to fly at the same speed and in the same direction as the wind. The technique of trajectory analysis, which traces the path of a parcel of air over time, can be used to examine their windborne displacements and the results included in national and regional pest management and forecasting systems.

Wind speed and direction continuously change with time and altitude so that data on the timing, height and duration of insect flight are essential for trajectory analysis to be applied successfully.

Migration studies in IPM: remote sensing and Geographical Information Systems

J. PENDER

Satellite remote sensing identified areas of rice at different growth stages corresponding to different stages in the life history of the brown planthopper (a major pest of rice in Asia). A Geographical Information System (GIS) was used to assist classification of small cotton fields at risk from the cotton boll weevil by integrating remotely sensed, topographic and field boundary data.

Forecasting desert locust population change and movements requires the comparison of current data with large historical data sets. GIS provides an ideal tool for spatial integration of disparate information in the production of forecasts.

Migration studies in IPM: windborne dispersal of pathogens causing sigatoka leaf spots in banana and plantain

P. BURT

Sigatoka leaf spot of banana and plantain is caused by fungal infections. Yellow sigatoka is caused by *Mycosphaerella musicola* and black sigatoka by *M. fijiensis*. Both diseases affect quality and yield, and can cause major crop losses. The disease spreads through the introduction of infected material to previously uninfected areas and by the windblown transport of infective spores. The latter is the most likely explanation for long-distance (trans-oceanic and trans-continental) movements, but all the mechanisms of spreading are not wholly understood.

Work is currently in progress to determine the role played by wind in transporting infective spores over various distances, and how long such spores could remain viable in the atmosphere. An understanding of dispersal is the first step in forecasting the disease, thus enabling farmers to undertake economic control measures.

Isozyme and DNA polymorphisms in *Mycosphaerella fijiensis* and *M. musicola*, the fungi causing sigatoka leaf spots of banana

A. JOHANSON

Two forms of sigatoka leaf spots affect bananas and plantains. Yellow sigatoka is caused by the fungus *Mycosphaerella musicola* and black sigatoka by *M. fijiensis*. Both diseases are of economic importance, but black sigatoka develops more rapidly, and is more difficult to control than yellow sigatoka. It is often not possible to distinguish between the pathogens by symptoms or morphology alone. The genetic variability of the two species is currently being investigated. Polyacrylamide gel electrophoresis (PAGE) of soluble proteins was used to compare isolates from different geographical areas. Of the sixteen enzymes initially tested, several, including esterases, acid phosphatase, alkaline phosphatase and glucose phosphate isomerase, were differential for the species.

No differences have so far been observed within each species. The potential of genomic and mitochondrial DNA restriction fragment length polymorphisms (RFLPs) and random amplified polymorphic DNA markers (RAPDs) as a means of studying the population dynamics of these pathogens is being investigated.

Control of bacterial wilt

S. J. EDEN-GREEN, J. G. ELPHINSTONE*, S. FORDE*, P. JONES* and A. ROBINSON*

**Rothamsted Experimental Station, AFRC-IACR, Harpenden, Hertfordshire AL5 2JQ, UK*

Bacterial wilt is a major constraint on the production of a wide range of economically important crops throughout the tropics and sub-tropics. Banana, plantain, groundnut, potato, tomato, sweet pepper, eggplant, ginger and tobacco are amongst the crops affected by this disease, which is caused by *Pseudomonas solanacearum* and other related bacteria. Control of the disease can be achieved by location-specific integrated management, including the use of disease-free planting material, resistant or tolerant cultivars, avoidance of infection, and the development of strategies for suppressing the pathogen in infested soil. Current research conducted at Rothamsted Experimental Station aims to improve the performance of control strategies through the development and application of improved techniques for pathogen detection and characterization, a better understanding of the interaction between different bacterial strains, host cultivars and environmental conditions, and determination of mechanisms involved in the suppression of soil-borne inoculum potential.

More than 600 isolates of *P. solanacearum*, collected world-wide from diverse hosts and geographical origins, have been grouped according to the results of more than 20 biochemical tests. Specific host-pathogen interactions are being studied to select cultivars of various hosts with differential resistance to a range of bacterial strains. Host-pathogen interactions are strongly modified by changes in environmental conditions, particularly temperature. Monoclonal antibodies are under development for the selective identification of specific pathogen strains, whereas polyclonal antibodies are being used for non-selective detection systems for epidemiological research. Seed amendment with lime (5 t/ha CaO) and urea (200 kg/ ha) has been effective in reducing the severity of bacterial wilt under field conditions in Peru. The suppression of bacterial wilt in tomato seedlings has also been demonstrated *in vitro* by amendment of the nutrient solution with potassium nitrate.

Epidemiology of yam anthracnose

S. SIMONS[+] and A. SWEETMORE

[+]Department of Agriculture, University of Reading, Earley Gate, Reading RG6 2AT, UK

Yams are traditionally a subsistence crop grown by smallholders. Foliar anthracnose of yams is caused by the fungal pathogen *Colletotrichum gloeosporioides*. The disease has recently become devastating on popular varieties of *Dioscorea alata* in the Caribbean and is escalating in West Africa. Naturally occurring tolerant varieties are now being planted more extensively in the Caribbean - but a good correlation exists between these tolerant cultivars and inferior taste and cooking quality. Field surveys in Barbados were carried out in collaboration with the Caribbean Agricultural Research and Development Institute (CARDI) during the 1990 and 1991 growing seasons to monitor the patterns of spread of the disease. Results confirmed that high-rainfall areas experience more severe disease. Larger-scale growers dip cut tubers in benomyl before planting. In recent years, fungicides have been ineffective; the survey demonstrated that early application of fungicides, before symptoms are obvious, can slow the rate of spread of the disease and improve yield.

A scoring system was developed to quantify the severity of anthracnose on individual yam plants. Six categories were defined according to the percentage leaf area infected, with the emphasis on the earlier stages of disease. Previous scoring systems for yam anthracnose have fallen into two categories: (i) those which place an equal weight on all stages of disease development, and (ii) those which incorporate changes in leaf colour or texture into the severity score. The disadvantage of the former is that it does not provide information on the important initial stages of the epidemic; the second type of system can be misleading as the symptoms may vary with location and with different isolates of *Colletotrichum gloeosporioides*.

Characterization of the fungal pathogens of the sorghum shoot disease complex

A. M. JULIAN, B. E. V. THURLEY and B. PEACOCKE

Department of Agriculture, University of Reading, Earley Gate, Reading RG6 2AT, UK

Sorghum is susceptible to invasion by a large number of fungal pathogens, and under favourable climatic conditions yields can be severely reduced. The objective of this study is to identify factors which could be adapted to reduce disease levels under subsistence conditions, for example the use of resistant varieties or novel cropping strategies. The programme aims to clarify the nature of the host-pathogen interaction, and determine the relationship between fungal isolates of diverse geographical origin and resistant germplasm. Field trials are also being conducted at disease 'hot spots' in Africa in collaboration with the International Centre for Research in the Semi-Arid Tropics (ICRISAT), and local government research stations. Preliminary experiments have investigated the distribution of fungal pathogens, their effect on yield parameters, and disease epidemiology. (This project is funded by the Natural Resources Institute, Chatham, UK.)

Cowpea resistance to *Striga gesnerioides*

J. A. BAILEY, J. A. LANE and P. J. TERRY

Department of Agricultural Sciences, University of Bristol, Long Ashton Research Station, Bristol BS18 9AF, UK

Cowpea is the principal grain legume for smallholders in West Africa, forming a significant part of their diet. The parasitic plant *Striga gesnerioides* is a major constraint to cowpea production in these regions. Current methods of control based on hand weeding and crop rotation are not successful for smallholders. *Striga*-resistant cowpeas would provide the most readily applicable and most effective method of weed control. Recently, resistance to *Striga* was identified in material from Botswana and West Africa. These cowpeas are providing the basis for breeding resistant varieties and material will soon be available to farmers. An *in vitro* system for infecting cowpea seedlings with *S. gesnerioides* has been used to study the mechanisms of resistance of these new varieties. One mechanism is based on a necrotic 'hypersensitive' response, and the other on the inability of the parasite to develop normally on resistant roots. The *in vitro* system has also been used to screen cowpea germplasm for additional sources of resistance. Two landraces of cowpea have been identified with good resistance to *Striga*, and these will be tested in Africa for agronomic qualities. Recently, the *in vitro* system has been adapted to study the infection process of *Striga* on cereals such as maize and sorghum. The technique is being used to determine whether the mechanisms of resistance that exist in cowpea are also present in cereals.

Screening for resistance to rice nematodes

R. PLOWRIGHT

International Institute of Parasitology, 395A Hatfield Road, St Albans, Hertfordshire AL4 0XU, UK

Methods of screening for resistance in different rice nematode-crop combinations have been examined. In deep-water rice a specific resistant host response to infection by *Ditylenchus angustus* has been identified. The resistant response, which appears to be a hypersensitive reaction, differs qualitatively from the susceptible response, enabling genotype selection without resort to laborious nematode counts. Antibodies have been used to quantify nematode numbers in roots of lowland and upland rice. Polyclonal antisera were found to cross-react, even between nematode species as disparate as *Meloidogyne graminicola* and *Pratylenchus zeae*, and therefore would only be suitable for quantifying nematodes in experimental situations such as germplasm or nematicide screening where known species of nematode were being used.

Control of root-knot nematodes with a biological control agent, *Pasteuria penetrans*

S. R. GOWEN

Root-knot nematodes (*Meloidogye* spp.) are a major pest of vegetables and fruit crops throughout the tropics. The deformation and growth restriction of the roots seriously diminishes their function and can predispose the plant to other pathogens. Populations of root-knot nematodes are difficult to control because of their wide host ranges and high rates of reproduction. Each female nematode that develops may produce up to 1000 eggs. In tropical soils, the generation time from egg to egg may be only 20-30 days, thus several generations may occur within one crop cycle. A successful control strategy will need to prevent root invasion and/or prevent females producing eggs. *Pasteuria penetrans* is a bacterial parasite of *Meloidogyne* spp. that occurs widely in tropical soils. It has many attributes of a good biocontrol agent, but cannot be produced in sufficient quantities to treat large areas. It can, however, be produced on its host and deployed in small plots and gardens. Results from field tests in Malawi suggest that cropping practices might be developed that increase the levels of *P. penetrans* spores in soil over the number of crop cycles. Successful deployment of *P. penetrans* will depend on the ability to manipulate the concentration of spores in soil to a level that ensures a significant proportion of the nematodes become infected. It is expected that the best chance of realizing this is by integrating the culture of *P. penetrans* with other nematode control strategies such as crop rotation and use of non-host crop varieties.

Biorational research aimed at developing pest control using naturally occurring agents

Insect Pathology Resource Centre

Natural pathogens of insect pests, such as viruses and bacteria, are being developed at NRI as environmentally friendly control methods. Their specificity allows them to be safely used without the risks associated with intensive use of many chemical insecticides. Candidate agents are investigated and assessed in the laboratory. Production systems and formulations for suitable agents are tested. Appropriate techniques are transferred to recipient countries where they are further developed. Examples include the use of nuclear polyhedrosis virus to control *Spodoptera littoralis*, which has been field tested in Egypt and Thailand.

Chemical ecology at NRI

Chemical Ecology Resource Centre

Pheromones are chemicals produced by organisms which affect the behaviour of other individuals of the same species, e.g. sex pheromones attract members of the opposite sex for mating. Identification and synthesis of pheromones can provide new technologies for use in pest management, e.g. traps baited with pheromones can be used for monitoring or control of insect pests, and permeation of the atmosphere with synthetic pheromone can be used to control insect pests by mating disruption. The NRI Chemical Ecology Resource Centre has facilities for identification, synthesis and formulation of insect pheromones, and wide experience of their use in developing countries. Particular examples are the use of pheromone-baited traps for monitoring East African armyworm *Spodoptera exempta*; the larger grain borer *Prostephanus truncatus* in many African countries; and the cotton bollworm *Helicoverpa armigera* in India. Formulations for use with pheromones in mating disruption have been developed at NRI and these are now commercially available. They have been used to control pink bollworm, *Pectinophora gossypiella*, on cotton in Egypt and Pakistan; spiny bollworms, *Earias* spp., in Pakistan; and rice stem borers in India and Spain. The techniques developed at NRI have also been used to identify attractants for tsetse flies and for New World screwworm flies.

Improving pesticide use in developing countries

Agrochemicals Resource Centre

Pesticides are often applied with inappropriate or badly adjusted equipment, by operators with little perception of the hazards involved. Monitoring of spraying improves safety and accuracy of application, reducing hazards to man and the environment, and ensuring efficient, cost-effective use of pesticides.

Dyes and fluorescent agents may be used as tracers of pesticide movements, and patterns and levels of spray deposition can be demonstrated. Skin contamination from spraying can be high, and concentrated on particular areas of the body, showing where protective clothing is most needed. Rapid, accurate sampling of sprays gives a basis for recommendations to improve application.

In developing countries pesticide containers are valuable storage vessels, and a source of raw materials for a range of uses including cooking utensils. Containers are often inadequately washed prior to re-use. Methods of washing containers were tested. Extended soaking times are necessary to remove chemical absorbed into the container lining, particularly with polythene materials. High-pressure hosing or agitation of the water may accelerate the cleaning process. Ideally containers should be designed to be unsuitable for re-use after they have been emptied.

Pesticides are vital components of agricultural systems and public health programmes, but their use needs to be controlled to prevent hazards to operators, the general public and the environment. Trained manpower is essential for the effective control and use of pesticides. A number of courses, including Principles of Pesticide Registration and Control, Pesticide Residue Analysis, and Safe Handling and Application of Pesticides, can be arranged either at NRI or at local venues.

Field methods for assessing pesticide effects on ecological processes in tropical soils

I. GRANT

Technical problems and the costs of ecological monitoring to evaluate hazards from agrochemicals have led to increased reliance on predictive environmental impact assessments. In the absence of empirical studies, these depend heavily upon extrapolating bioassay results and other registration data to the field. The value of these forecasts can be seriously compromised in the climatic extremes of many tropical environments, as studies of agrochemical behaviour are beginning to show. New techniques and tools to monitor key soil processes *in situ* or under field conditions are being developed. Criteria for design of ecological monitoring techniques in the tropics include the following:

* sensitive or important functional processes are targeted
* techniques of quantitation are swift, simple and inexpensive
* concessions made to accuracy and precision in the field do not compromise assessment
* apparatus is truly portable or readily constructed overseas
* potential for technology transfer is intrinsic.

Ammonification, nitrification, biological nitrogen fixation and carbon mineralization are important for the maintenance of fertility in tropical soils, where low nutrient and organic matter content is characteristic of many savanna soils. Fertilizers and pesticides can stimulate or suppress those processes under the control of relatively few micro-organisms, e.g. nitrification and BNF. Repeated or ill-timed use of agrochemicals on crops may affect all these key processes, interfering with nutrient recycling or reducing the efficiency of commercial fertilizers. Seasonal influences of soil moisture and temperature provide a yardstick of natural constraints on soil processes, against which the risk from agrochemicals can be gauged.

A coffee can pushed into the soil is fitted with inlet and outlet ports through which dry air is passed from a mass-flow pump to a battery-powered infra-red gas analyser (IRGA). After flushing the headspace, the difference between ambient and flow-through CO_2 concentrations after 4 minutes was used to estimate respiration in sprayed and unsprayed areas. Sampling precision for n=5 ranged from 4-27%

Semi-continuous measurement of microbial respiration in organic-matter-amended soil at 60% FC has been made in food containers kept at ambient shade temperatures, the lids being fitted only during flushing of CO_2 to the IRGA. The monitoring period can be extended to accommodate the anticipated half-life of the pesticide in soil. Coefficients of variation ranged from 10-40%.

Some commercial gas chromatographs (GCs) are 'luggable' but still require compressed carrier or ionization gases that are soon exhausted or are unavailable overseas. A portable GC has been developed which uses air as a carrier and semi-conductor gas sensors as detectors, giving sufficient sensitivity, stability and reliability for measuring a range of gases (including CH_4, CO, H_2) at low cost. Estimates of N_2 fixed are obtained by assuming a 12-hour fixation period and a molar ratio of 3:1 (C_2H_2 reduction : N_2 fixation). For the growing season, this would equal 96 kg N/ha for habitats dominated by *Azolla* , and 21 kg N/ha for algae. As fertilizer nitrogen and phosphorus suppress BNF, more information on the dynamics of natural processes will result in management of nutrient resources to better advantage. Soils amended with organic matter or ammonium salts to measure ammonification or nitrification are maintained at 70% FC and ambient shade temperatures in food containers, some of which are exposed to spraying of pesticides. Treated and untreated soils are extracted periodically with KCl or distilled water to determine NH_4^+ or NO_3^- by colorimetric methods or ion- selective electrodes.

Leaf, stem and root litter has been prepared for microbial decomposition by soil detritivores, reducing particle sizes and increasing the surface area for microbial attack. Insecticides can affect populations of detritivores, heterotrophic micro-organisms and therefore litter processing. Bags containing litter are buried in sprayed and unsprayed soils and retrieved at intervals to weigh the remaining litter. Varying the mesh width of the bags provides information on the type of organism involved.

The effects of DDT used to control tsetse fly on woodland invertebrates in Zimbabwe

C. C. D. TINGLE

Despite selective application, DDT applied for tsetse fly control persists in hot spots on tree bark (up to 93 µg/cm) and in soil (up to 80 µg/cm), constituting a risk for non-target wildlife. No differences were found in diversity of epigeal invertebrates pitfall trapped in sprayed and unsprayed areas, and any effect of DDT on faunal composition of trap catches was found to be secondary to differences caused by natural variation and other environmental factors. Residue levels in termites, tenebrionid beetles and ants are reported, showing that high levels can accumulate in some insects, particularly ants. *Camponotus* spp. (Formicidae: Formicinae) showed no evidence of population changes in sprayed areas, but were important in carrying DDT residues into the food chain, causing population decline in two species of woodland birds.

Effects of DDT on birds in Zimbabwe

R. J. DOUTHWAITE

Effects of DDT residues on bird populations in the tropics are unknown. In Zimbabwe, DDT is used to control tsetse flies and mosquitoes. Since 1968, tsetse flies have been eradicated from 40 000 km^2 of woodland by using DDT. The effects on wildlife are being assessed in a joint Zimbabwe/UK government study. It was recently decided to phase out the use of DDT for tsetse fly control by 1995.

Numbers of most species vary more between years and habitats than between DDT-treated and untreated woodland. The white-headed black chat (Turdidae: *Thamnolaea arnoti*) and red-billed wood hoopoe

(Phoeniculidae: *Phoeniculus purpureus*) are exceptions. Both breed successfully in sprayed woodland but are almost exterminated by repeated spray treatments. Both species eat arthropods from tree trunks and can accumulate high levels of DDT and its metabolites (<2500 p.p.m. on a whole-body lipid basis). However effects are temporary and population recovery was found to be well advanced in heavily sprayed woodland seven years after the final treatment.

More birds were detected at the edge of the sprayed area. Numbers in the untreated area were slightly reduced. Annual treatments reduced numbers by 90% in three years. High levels of embryonic DDE, eggshell thinning and breeding failure have been found in the African goshawk (Accipitridae: *Accipiter tachiro*) and fish eagle (Accipitridae: *Haliaaetus vocifer*).

Effects on the fish eagle population have been studied. Eggshell thickness and the t-DDT content of eggs have been found to vary inversely. Despite poor hatching success the density of occupied nests at the eastern end of Lake Kariba remains high. Chick predation by man, exacerbated by a loss of safe nest sites due to elephant damage onshore and wave action offshore, may pose a bigger threat to fish eagle numbers than the present use of DDT.

Food safety and quality assurance

Microbiology and Fermentation Section

Farmers, food processors and traders in developing countries face a challenge to grow, process and maintain sufficient safe and wholesome food to satisfy the needs of domestic consumers and the increasing demands of export markets. Reduction in food quality leads to:

* substantial losses in export/domestic markets
* disease and death in man and animals
* poor nutritional value.

Both fresh and processed foods are susceptible to spoilage and contamination by bacteria, yeasts and moulds. Some micro-organisms can spoil food, changing its appearance, texture and odour, making it unacceptable to the consumer and leading to wastage. Bacteria such as *Listeria monocytogenes* and *Salmonella* can cause food poisoning and even death. Growth of moulds in foods and animal feeds can result in the formation of chemicals (mycotoxins) which may cause diseases such as liver cancer and ultimately lead to death. Aflatoxin, a most potent carcinogen, can be passed along the food chain to humans through the milk of cattle fed on mouldy feed. Other substances which are harmful to man may either be naturally present in a food, or introduced at any stage of production. Cassava, a staple starch crop in many parts of the developing world, contains a compound which can break down to give cyanide. If cassava is not properly processed, consumption of products containing high cyanide levels can result in conditions such as goitre. Crops in the field or in storage are prone to attack by insects. In order to improve crop yields and reduce losses, pesticides are often applied, leaving harmful residues in the food.

NRI has an international reputation for research, development and technology transfer in developing countries, addressing problems linked to reducing crop losses, improving and maintaining food quality, and maximizing economic returns. Our experience focuses on:

* development of sampling protocols
* detection, prevention and control of food spoilage and storage organisms, pathogens and their toxins
* determination of pesticide levels
* adaptation of food storage, processing and preservation technologies
* analysis of anti-nutritional factors
* trouble-shooting in food processing
* knowledge of international trade legislation and standards
* training in the UK and overseas.

NRI holds specialist courses which relate to improved food quality and quality assurance. These are aimed at strengthening technical capabilities of individuals from developing countries. Courses are available in Mycotoxins, Basic Food Microbiology, Storage of Durable Agricultural Products in the Tropics, Post-harvest Fruit, Vegetable and Root Crop Technology, and Handling and Quality of Fish in the Tropics.

Biomass energy at NRI

Biomass Energy Section

The production of charcoal in developing countries is a widespread and long-established craft providing a valuable product for both domestic and industrial markets. Sometimes there is a lack of control over the carbonization process with the traditional method of manufacture. This can result in low wood-to-charcoal conversion efficiencies and a charcoal product of variable quality which is contaminated with soil and stones. The Biomass Energy Section carries out technical evaluations of traditional charcoal-making methods and gives advice on their efficiencies, quality of charcoal and ways for possible improvement. In addition, the Section has developed and introduced three methods that can consistently produce high yields of good quality charcoal.

In developing countries it is common to find considerable quantities of agricultural and forestry particulate residues (e.g. sawdust, rice husks, groundnut shells) generated by local industries. These residues, a potential source of energy, are often considered a waste product and create problems of disposal. Difficulties arise, however, when attempting to burn these materials. Their often high moisture content and relatively low calorific values, coupled to difficulties of mechanical handling, make them an unsuitable fuel for standard solid-fired systems.

Two burner systems have been designed and developed that can efficiently combust a range of these materials. The systems typically operate by blowing the biomass residue into a furnace chamber, where it then combusts whilst in suspension. During carbonization of biomass materials, approximately 50% of the energy, mainly in the form of smoke containing combustible gases and volatiles, is normally lost to the surroundings. The other 50% of the energy remains in the charcoal product. Two systems have been developed which recover the majority of heat normally lost, as well as virtually eliminating the smoke problem. The systems burn the gases and volatiles as they evolve and the heat generated may be utilized in any associated industrial process.

Motive power requirements are common in many industrial processing and agricultural operations. There also exists a demand for small- to medium-scale electricity generation in industry and rural areas. Existing motive power and electricity generation systems often rely on imported fossil fuels to operate. In many developing countries there is a desire to reduce these imports and work towards self-reliance. The Biomass Energy Section has studied and evaluated a range of experimental, pilot and commercial systems for motive power and electricity generation fuelled by biomass. In addition a number of experimental and pilot motive power systems fuelled by charcoal producer gas and vegetable oil/diesel fuels have been developed.

Technical evaluations of traditional biomass energy systems are a necessary precursor to most projects. The Section has conducted numerous evaluations of biomass combustion systems and charcoal-making methods and advised on thermal efficiencies and ways to bring about any necessary improvements. Reductions in industrial energy usage can be an important way of saving biomass and other types of fuel resources. To assist, the Section offers to conduct industrial energy surveys and audits and identify where thermal savings may be made.

Many developing countries have local organizations and institutions with the facilities to carry out related biomass energy work and may wish to strengthen their local capabilities. To help, the Biomass Energy Section provides training both at NRI and overseas.

Database use in migration studies

M. HAGGIS

The African armyworm *Spodoptera exempta* is a major pest of cereal crops and rangeland, especially in East Africa. A network of light and pheromone traps is used to monitor moth migrations. Records of trap catches and larval outbreaks since 1969 are stored in WORMBASE, a database and expert system especially designed to assist forecasting when and where infestations are likely to occur.

WORMBASE

Design and implementation	Silwood Centre for Pest Management
Expert system design	Desert Locust Control Organization for Eastern Africa
End users	National and regional armyworm forecasters

Migration studies - the use of databases in response to queries

C. DAVIES

Rice colonized by the brown planthopper (BPH; *Nilaparvata lugens*) shortly after transplanting is most likely to suffer heavy damage.

Q: Is rice in Vietnam transplanted in November?

A search of **CROPSYS** (a rice cropping system database) using the keywords **TRANSPLANT**, **VIETNAM** and **NOVEMBER** retrieves six items:

*(1195)
COUNTRY: **Vietnam**
PLACE: North Vietnam
CULTIVATION: **transplant**
PERIOD: **November** week 3 and 4
SEASON: winter-spring
TYPE CROP: early
CROSS-REFERENCE TO PESTBIB: 1031

*(930)
COUNTRY: **Vietnam**
PLACE: Saigon, Ho Chi Minh City
LATLONG: 10°46'N, 106°43'E
CULTIVATION: **transplant**
PERIOD: July, September, October, **November**
CROSS-REFERENCE TO PESTBIB: 135

*(924)
COUNTRY: **Vietnam**
PLACE: Thanh-Hoa
LATLONG: 19°19'N, 105°48'E
CULTIVATION: **transplant**
PERIOD: July, August, **November**, December, January
CROSS-REFERENCE TO PESTBIB: 135

*(921) COUNTRY: **Vietnam**
PLACE: Hue
LATLONG: 16°28'N, 107°35'E
CULTIVATION: **transplant**
PERIOD: May, June, **November**
CROSS-REFERENCE TO PESTBIB: 135

*(918) COUNTRY: **Vietnam**
PLACE: Bac Ninh
LATLONG: 21°00'N, 106°00'E
CULTIVATION: **transplant**
PERIOD: July, **November**, June week 4, December, January
CROSS-REFERENCE TO PESTBIB: 135

*(902) COUNTRY: **Vietnam**
PLACE: South Vietnam
CULTIVATION: **transplant**
PERIOD: October weeks 3, 4, **November** weeks 1, 2
TYPE CROP: secondary
CROSS-REFERENCE TO PESTBIB: 65

A: YES, rice IS transplanted in November throughout Vietnam and could be at risk if colonized by BPH.

CROPSYS cross-references to **PESTBIB** (a bibliographic reference database covering biogeographical research topics), and lists the three sources of this information:

REFERENCE NO.65
HARDJAWINATA S., 1980. Macroclimatic aspects of rice production in Southeast Asia. pp. 57-68. In Proceedings of a Symposium on the Agrometeorology of the Rice Crop, Cowell R.L., (ed.). Los Banos: International Rice Research Institute. xviii+254pp.

REFERENCE NO.135
NUTTONSON M.Y., 1963. The physical environment and agriculture of Vietnam, Laos and Cambodia, a study based on field survey data and on pertinent records, material and reports. Washington D.C.: American Institute of Crop Ecology. (viii)+137pp.

REFERENCE NO.1031
VU TUYEN HOANG, 1986. Rice production in Vietnam. International Rice Commission Newsletter 35(2): 9-19.

The latitude and longitude values obtained from CROPSYS can be plotted to show areas potentially at risk.

LIST OF PARTICIPANTS

Dr El-Tayeb A . Babiker
Under Secretary of Agricultural Services
Ministry of Agriculture, Animal and Natural Resources
PO Box 285
Khartoum
Sudan

Dr Callistus W. Baliddawa
Makerere University
PO Box 7062
Kampala
Uganda

Dr Jeffery W. Bentley
Departamento de Proteccion Vegetal
Escuela Agricola
Pan Americana
PO Box 93
Tegucigalpa
Honduras

Mr C. Boisson
Institut Francais de la Recherche Scientifique pour leDeveloppement Scientifique en Co-operation (ORSTOM)
Laboratoire de Phytopathologie Tropicale
BP 5045
34032 - Montpellier Cedex J
France

Dr Liz Chadd
Farmer Education and Training Section (FEATS)
ICI Agrochemicals
Fernhurst
Haslemere
Surrey GU27 3JE
UK

Dr Robert Chambers
Institute of Development Studies
University of Sussex
Brighton BN1 9RE
UK

Dr Andrew Daudi
Bvumbwe Research Station
PO Box 5748
Limbe
Malawi

Ricardo T. Deang
Pesticide Technical Services Chief
Fertilizer & Pesticide Authority
4th Floor, Raha Sulayman Building
Benavidez St
Makati
Metro Manila
Philippines

Mr Lassana S. Diarra
Service de la Protection des Vegetaux
BP 1560
Bamako
Mali

Dr John Farrington
Overseas Development Institute
Regent's College
Inner Circle
Regent's Park
London NW1 4NS
UK

Professor Jacob Foko
UCD Department of Plant Protection
PO Box 222
Dschang
Cameroun

Mr Leopold Gahamanyi
Director
Institut des Sciences Agronomiques du Rwanda
BP 138
Butare
Rwanda

Dr David J. Greathead
Director
International Institute of Biological Control
Silwood Park
Ascot
Berks SL5 7PX
UK

Dr Ian Haines
Overseas Development Administration
94 Victoria Street
London SW1E 5JL
UK

Dr Winfred N. O. Hammond
International Institute for Tropical Agriculture
Biological Control Centre for Africa
BP 08-0932 Cotonou
Republic of Benin

Mr Peter Jowah
Cotton Research Institute
Private Bag 765
Kadoma
Zimbabwe

Mrs Mary G. Kariaga
Crop Protection Research Co-ordinator
National Agricultural Laboratories
PO Box 1221
Nairobi
Kenya

Dr Gilbert Kibata
Crop Protection Research Co-ordinator
National Agricultural Laboratories
PO Box 14733
Nairobi
Kenya

Mr Gapi Kula
PNG Coffee Industry Cooperation
PO Box 105
Kainantu EHP
Papua New Guinea

Ms Carmen Malina
Institute of Development Studies
University of Sussex
Brighton BN1 9RE
UK

Mr Urban W. Martin
Inter-American Institute for Cooperation in Agriculture
Botanical Gardens
Roseau
Dominica
West Indies

Mr S. M'Boob
Senior Regional Crop Protection Officer
FAO Regional Office for Africa
PO Box 1628
Accra
Ghana

Mr J. W. Mchowa
Makoka Agricultural Research Station
Private Bag 3
Thondwe
Malawi

Dr Frans Meerman
Tropical Crop Protectionist
Department of Entomology
Wageningen Agricultural University
PO Box 8031
6700 EH Wageningen
The Netherlands

Dr P. Muchena
Director
Plant Protection Research Institute
PO Box 8100
Causeway
Harare
Zimbabwe

Dr Phillip Nkunika
Department of Biology
University of Zambia
PO Box 32379
Lusaka
Zambia

Dr Brigitte T. Nyambo
International Centre for Insect Physiology and Ecology
PO Box 3072
Nairobi
Kenya

Dr John E. Ohabuike
Plant Protection Expert
Lake Chad Basin Commission
BP 727
N'Djamena
Republic of Chad

Mr Kirifi Pouono
Tropical Agriculturalist
Department of Agriculture, Forests and Fisheries
Nuu Crop Development and Research Station
PO Box 1587
Apia
Western Samoa

Dr Janice C. Reid
Caribbean Agricultural Research and Development Institute
PO Box 113
Mona Campus
Kingston 7
Jamaica

Mr John Rowley
OXFAM
274 Banbury Road
Oxford OX2 7DZ
UK

Mr A. A. Seif
Senior Plant Pathologist
Kenyan Agricultural Research Institute
PO Box 14733
Nairobi
Kenya

Dr Theresa Sengooba
Director
Namulonge Research Station
PO Box 7084
Kampala
Uganda

Mr Habila A. Sharah Uvu
Ministry of Agriculture
PMB 1047
Maiduguri
Borno State
Nigeria

Dr Barend Verachtert
Plant Genetic Systems NV
J Plateaustraat 22
B9000 Ghent
Belgium

Dr William Vorley
Farmer Support Team
Ciba-Geigy AG
Basel
Switzerland

Dr Florence M. Wambugu
c/o Dr Robert Horsch
Monsanto Company
700 Chesterfield Village
Parkway
St Louis
Missouri 63198
USA

Mr M. J. Whitaker
Product Usage Manager
ICI Agrochemicals
Fernhurst
Haslemere
Surrey GU27 3JE
UK

Michael Pickstock
Sarah Reynolds
Media Projects
Fressingfield
Eye, Suffolk IP21 5SA
UK

Dr Alan Jackson
Dr W Treitz
CTA
Postbus 380
6700 AJ Wageningen
The Netherlands

Dr R. W. Gibson
Mr M. Iles
Dr N. D. Jago
Dr L. Kenyon
Mr D. Lyon
Mr T. J. Perfect
Ms A. Sweetmore
Ms K. Wilson
Dr T. G. Wood
Mrs P. Woodman
NRI
Central Avenue
Chatham Maritime
Kent ME4 4TB
UK

ABBREVIATIONS

ACMV	African cassava mosaic virus
ACORD	Advisory Council on Research and Development (Europe)
ADB	Asian Development Bank
ADMARC	Agricultural Marketing and Development Corporation (Malawi)
AVRDC	Asian Vegetable Research and Development Center
BCP	Biological Control Programme (of IITA)
Bt	*Bacillus thuringiensis*
CAB	CAB International, formerly Commonwealth Agricultural Bureau
CARDI	Caribbean Agricultural Research and Development Institute
CBI	Caribbean Basin Initiative
CDR	complex, diverse and risk-prone agriculture
CGIAR	Consultative Group on International Agricultural Research
CGM	cassava green mite
CIAT	Centro Internacional de Agricultura Tropical
CIP	Centro Internacional de la Papa (International Potato Centre)
CM	cassava mealybug
COSCA	Collaborative Study of Cassava in Africa
CTA	Centre Technique de Coopération Agricole et Rurale (Technical Centre for Agricultural and Rural Co-operation)
DDT	dichloro-diphenyl-trichloro-ethane
EMBRAPA	Empresa Brasileira de Pesquisa Agropécuaria
FAO	Food and Agriculture Organization of the United Nations
GNP	gross national product
IARC	international agricultural research centre
ICIPE	International Centre for Insect Physiology and Ecology
ICLARM	International Center for Living Aquatic Resources Management
ICP	insecticidal crystal protein
ICRISAT	International Centre for Research in the Semi-Arid Tropics
IIBC	CAB International Institute of Biological Control
IITA	International Institute for Tropical Agriculture
IPM	integrated pest management
IRRI	International Rice Research Institute
KARI	Kenyan Agricultural Research Institute
NAL	National Agricultural Laboratories, Nairobi, Kenya
NARS	national agricultural research systems
NGO	non-governmental organization
NRI	Natural Resources Institute
ODA	Overseas Development Administration (UK)
OECS	Organization of East Caribbean States
OXFAM	Oxford Committee for Famine Relief
PCCMA	Central American and Caribbean Programme for Food Improvement
PPE	personnel protective clothing and equipment
SA	sustainable agriculture
SAREC	Swedish Agency for Research Co-operation with Developing Countries
SNPV	Service National de Protection Vegetaux (Mali)
TOT	transfer of technology
ULV	ultra-low volume
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
WHO	World Health Organization

THE TECHNICAL CENTRE FOR AGRICULTURAL AND RURAL COOPERATION (CTA)

The Technical Centre for Agricultural and Rural Cooperation (CTA) operates under the Lomé Convention between member States of the European Community and the African, Caribbean and Pacific (ACP) States.

The aim of the CTA is to collect, disseminate and facilitate the exchange of information on research, training and innovations in the spheres of agricultural and rural development and extension for the benefit of the ACP States.

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