Community-Based and Environmentally Safe Pest Management

Edited by R. K. Saini and P. T. Haskell

CTA

ICIPE ALUMNI

ICIPE

Proceedings of a Workshop held at the International Centre of Insect Physiology and Ecology, Duduville, Nairobi, May 1991

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 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.

To achieve this aim, CTA commissions and publishes studies; organises and supports conferences, workshops and courses; supports publications and translations; and offers an extensive information service.

Postal address: Postbus 380, 6700 AJ Wageningen, Netherlands
Telephone: (31) (0) (8380)-60436
Telex: (44) - 30169 CTA NL
Fax: (31) (0) (8380)-31052

Community-Based and Environmentally Safe Pest Management

Edited by R. K. Saini and P. T. Haskell

Proceedings of a Workshop held at the
International Centre of Insect Physiology and Ecology,
Duduville, Nairobi, May 1991

Published and printed by

ICIPE SCIENCE PRESS
P.O. BOX 72913
NAIROBI, KENYA
TELEPHONE: (0254) 442012
FAX: (02254) 442469

Edited by

R. K. Saini and P. T. Haskell

ISBN: 92 9064 062 6

December, 1993

Acknowledgements

The Organisers of the Symposium wish to extend their deep appreciation to the following institutions for their financial and organisational support without which the mounting of this Symposium would not have been possible:

- Technical Centre for Agricultural and Rural Cooperation (CTA), Wageningen, The Netherlands
- United Nations Educational, Scientific and Cultural Organisation (UNESCO), the Regional Office for Science and Technology in Africa (ROSTA)
- The International Centre of Insect Physiology and Ecology (ICIPE)
- ICIPE Alumni Association

We are also grateful to CTA for their generous support towards the publication of the proceedings.

Preface

The Alumni Association of the International Centre of Insect Physiology and Ecology (ICIPE), together with its parent body, ICIPE, held the Symposium on Community-Based and Environmentally Safe Pest Management from 6th to 9th May 1991, at Duduville, Nairobi, Kenya. The Symposium was organised keeping in view the Alumni Association's objective to promote and organise programmes of bringing together ICIPE friends and staff in the pursuit of common interests, and to encourage scientific and training exchanges not only amongst those undertaking fundamental research on selected insect pests, but also those who are applying this knowledge to the problems of sustainable integrated pest and vector management.

This Symposium was an important milestone because it contributed towards a better understanding of the components required for developing sustainable community-based pest management, as well as marking a new departure, as it was one of the first of its kind in which a large proportion of the papers focused on the cultural and socio-economic context for effective pest and vector management. The conference affirmed that the small farmer sector is one of the most important in the African economy; and emphasised the need for it to be recognised and supported by all concerned so that it can realise its full potential as a primary productive community.

The Symposium was divided into eight topics, all of which were explored from the perspective of ICIPE's work, and its world context:

1. Techniques and Components of Pest Management Systems
2. Insect Population Dynamics in the Development of Pest Management Strategies
3. Contribution of Chemical Ecology, Behaviour and Physiology to Pest Management

4. Community-Based Vector Management
5. Community-Based Crop Pest Management
6. Socio-Economic Aspects of the Interface between Pest Management, Technology and Rural Communities
7. Information, Networking and Development of Human Resources for Pest Management
8. Pest Management and Human Safety

To address these issues, over 100 active scientists were assembled. Altogether 29 presentations were made including a video on "Participatory Research with Women Farmers" (conceived by M. P. Pimbert, of ICRISAT, and presented by K. F. Nwanze). This book records 15 of these presentations.

I am confident that all IPM specialists concerned with the development of sustainable pest management technologies will find this book a most notable publishing event. I hope that the Alumni Association will continue to organise such symposia on a regular basis, so that scientists involved in fundamental research and those involved in applying this knowledge towards sustainable agricultural production can meet to gauge the critical scientific advances being made as well as the potential technological developments that arise from them.

I wish to warmly acknowledge the work of the Editors, Dr. R. K. Saini and Prof. P. T. Haskell, for their hard work in bringing this book into shape from the original manuscripts. I wish to thank the Organising Committee for the high standards they have set.

PROF. THOMAS R. ODHIAMBO
Director, The International Centre of
Insect Physiology and Ecology (ICIPE)

Contents

Community-Based Pest Management — The Importance of the Small Farmer Sector

P. T. Haskell

School of Pure and Applied Biology, University of Wales, Cardiff

KEYNOTE ADDRESS

I am glad to give this keynote paper for two reasons. The first is that I have for the past 20 years or more been a strong advocate of pest management as the best answer to agricultural pest problems and the second is that as chairman, of the ICIPE Alumni Association, I feel that this first symposium we have initiated with ICIPE opens the way for further collaborative efforts of all types between the two organisations.

The symposium also marks a new departure as I believe it is one of the first in which a large proportion of the papers are about the sociology and socio-economic background to pest management. This has roots in ICIPE's own experience; it long ago accepted, as have all organisations dealing with pest control in agriculture and public health, that the pest management technique is the best conceptual approach, and it has for a long time carried out much basic entomological research into various aspects of IPM systems.

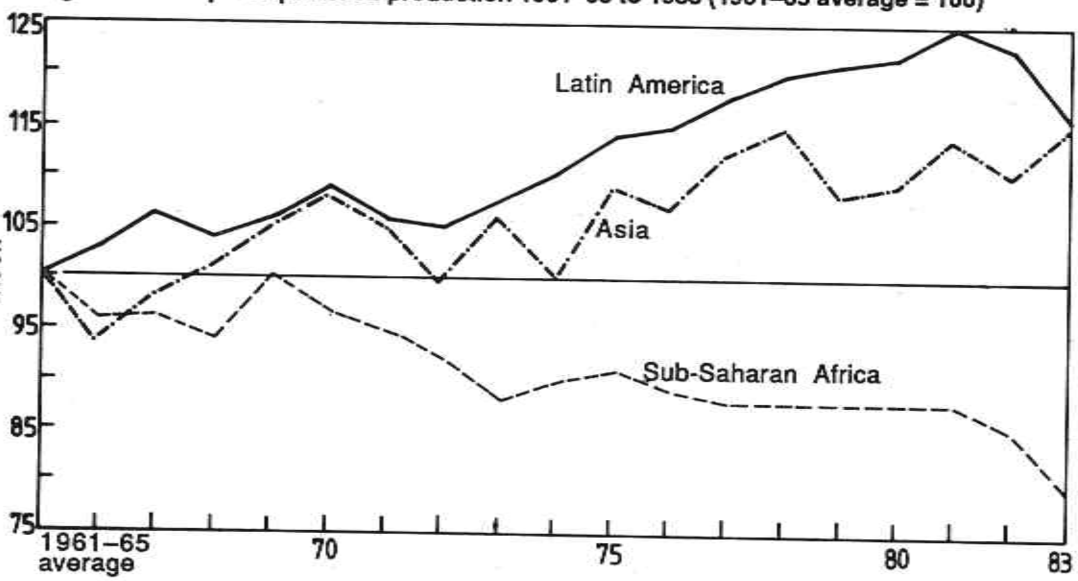
But it also began to look at the practical application of this system to small farmer problems; it was not of course alone in this and I think that probably the International Rice Research Institute (IRRI) was first in the field, where the sociological research carried out by Grace Goodell led her to the conclusion that some aspects of the IPM policy were wrongly based and would not benefit small farmers at all (Goodell, 1984). This finding was backed up by several IRRI scientists, and led to important changes in the direction of IRRI research. But whoever was first in the field, ICIPE was close behind.

It is clearly a waste of time and money if scientists produce crop varieties or pest control techniques which farmers can't or won't use because they do not fit in with their traditional farming system, which includes not only their land, crops, animals and tools but their family and its needs, their community and its needs and the political, economic and religious background to all this. We shall be hearing more about all these things in our meeting but in this introductory talk I want to set out some perspectives and suggest some possible lines for future work as a background to subsequent sessions.

To begin with, the overall background to our meeting has to be the very sad and very serious state of Africa today. A few days ago I was watching the Princess Royal on British television asking the public to give $2.5 million for the Save the Children Fund work in Africa—particularly Sudan, Ethiopia, Angola and Mozambique. The money will be given, it will be spent carefully on projects designed to develop sustainable agriculture—and it will be a drop in the bucket.

Look at this World Bank figure of per capita food production in three continents; it shows the serious and continuing decline in African food production over many years (Fig. 1) as compared with Asia and Latin America.

Fig.1. Index of per capita food production 1961–65 to 1983 (1961–65 average = 100)



Source: Based on data provided by the US Department of Agriculture.

While the nature of basic constraints and policy failures varies from country to country, some are widespread and general. These include war, climate and soil, population growth and health. Of the four countries at particular risk, that is Sudan, Ethiopia, Angola and Mozambique, all have had wars — or revolution — on their soil for many years.

Climate and conditions in much of Africa are harsh and extreme and soil is poor. In recent years the climatic conditions have been highly adverse — prolonged drought followed by short floods — and the prognosis is that this will worsen due to global warming.

Population growth is a basic and serious problem. Table 1, shows that sub-Saharan Africa leads the list as regards rates of increase while Latin America and Asia have much lower growth rates.

As regards health, sub-Saharan Africa is the only region in the developing world where nutrition has worsened in recent years. Some believe that general health standards are declining. For example, average life expectancy is about 50 years in Africa in general but is 40 in Somalia, while infant mortality is 77 per 1000 in Kenya but rises to 190 per 1000 in Sierra Leone. Few countries have developed primary health care systems, and even fewer provide health services for rural populations. All these factors have an effect on productivity and economic performance and also reduce the availability of human resources — both unskilled and trained. Importantly, all these factors adversely affect the small farmer community.

As regards agriculture and natural resources the recent droughts have emphasised the old African problems of soil erosion, deforestation and fuelwood — the latter becoming rapidly worse.

Although agricultural research in Africa has been heavily supported by the Consultative Group on International Agricultural Research (CGIAR) no "Green Revolution" has occurred in Africa comparable to the Asian experience except perhaps for the hybrid maize in the 60s. Little progress has been made in developing drought resistant and/or high yielding sorghum and millet, staple crops of arid zones. This relatively poor performance in agricultural research is not due to shortage of scientists — between 1970–1980 the number of research scientists grew from 1900 to 4000 and ICIPE has done a great deal in the training field to help produce this development.

Table 1. **Population policy indicators for selected countries with populations of 15 million or more, 1982**

Region and country	Total fertility rate	Family planning index	Policy Indicators: Demo-graphic data	Political commit-ment	Institu-tions		Family planning					Incentives and disin-centives			Birth quotas
	1982	1982	A	B	C	D	E	F	G	H	I	J	K	L	M
Sub-Saharan Africa															
Kenya	8.0	•	x	x		x	x	x							
Tanzania	6.5	•					x	x							
Nigeria	6.9	.					x								
Zaire	6.3	.													
Sudan	6.6	.	x				x								
Ethiopia	6.5	.													
Middle East & North Africa															
Egypt	4.6	•	x	x	x	x	x	x		x	x				
Morocco	5.8	•	x	x				x							
Turkey	4.1	•	x	x			x	x							
Algeria	7.0	•	x				x								

Region and country	Total fertility rate	Family planning index	Policy Indicators: Demo-graphic data	Political commit-ment	Institu-tions		Family planning					Incentives and disin-centives			Birth quotas
	1982	1982	A	B	C	D	E	F	G	H	I	J	K	L	M
Latin America and Caribbean															
Colombia	3.6	•	x	x	x		x	x							
Mexico	4.6	•	x	x	x	x	x	x	x	x					
Brazil	3.9	•	x				x	x							
Venezuela	4.3	•	x				x	x							
Peru	4.5	•	x	x		x	x	x							
South Asia															
Sri Lanka	3.4	•	x	x	x	x	x	x	x		x				
India	4.8	•	x	x	x	x	x	x	x	x	x				
Bangladesh	6.3	•	x	x	x	x	x	x	x	x	x				
Pakistan	5.8	•	x	x	x	x	x	x							
Nepal	6.3	•	x	x	x	x	x	x	x	x	x				
East Asia															
China	2.3	•	x	x	x	x		x	x	x		x	x	x	x
Korea, R. of	2.7	•	x	x	x	x	x	x	x	x		x	x		
Indonesia	4.3	•	x	x	x	x	x	x	x	x		x			
Malaysia	3.7	•	x		x	x	x	x	x	x					
Thailand	3.6	•	x	x	x	x	x	x	x	x					
Philippines	4.2	•	x	x	x	x	x	x	x	x		x			

Source: *World Development Report* 1984, Table 8.1

Note: The following countries with populations greater than 15 million were omitted because of lack of data: Afghanistan; Argentina; Burma; Islamic Republic of Iran; Democratic Republic of Korea; South Africa; Venezuela; and Viet Nam.

Key: ● = very strong index; • = strong; • = moderate; •=weak; · = very weak or none. For explanation of index, see *World Development Report* 1984, Population Data Supplement, table 6 and notes.

A–Published census data and data from other household surveys less than ten years old on fertility, mortality, and contraceptive use. B—Official policy to reduce population growth expressed by high officials and in a national development plan, sometimes including specific demographic targets. C—Existence of a population planning unit that integrates demographic projections into current economic plans and considers effect of policies on demographic parameters. D—Existence of a high level coordinating body, such a population commission, to set population policy, oversee implementation, and evaluate results of multisectoral policies. E—Government financial support of private family planning associations. F—Public family planning services. G—Family planning outreach, including community-based distribution systems or fieldworkers. H—Active use of mass media for information and education to promote family planning and small family norms. I—Publicly subsidised commercial sales of contraceptives. J—Elimination of all explicit and implicit subsidies that encourage large families (tax reductions for each child, family allowances, free or subsidised health and education services). K—Incentives to individuals or communities to have small families. L—Strong disincentives to discourage more than two births per woman, such as reduced services or an income tax for third and later-born children. M—Policy to set quotas on the number of births permitted annually in a community under which couples must obtain permission to have a child.

The problem seems to reside in the inefficient use of current resources. Some of this is due to duplication by aid donors — now being reformed — some to lack of information, some to insufficient or inefficient means of transfer of technology to farmers — and this is not helped by poor or non-existent extension services in most countries.

The picture is thus gloomy but there may be one ray of light, because one important outcome of a recent re-appraisal of the malaise of African agriculture is to focus more attention on small farmers (World Bank, 1984). The reasons for this are obvious. Look at Table 2, which shows that a staggering total of 88% of all land holdings in Africa are less than 5 hectares and 36% less than 1 hectare (World Bank, 1976). Because of this I pointed out (Haskell, 1975) over 15 years ago that a small and attainable rise of 5% in the production of small farmers over this large area would eliminate malnutrition. During the fifteen years, however, a great deal of research has been carried out, some of which has had the effect of directing attention from small farmers as "producers" to small

***Table 2*. Distribution of holdings by size**

	Latin America	Asia	Africa	Total
Number (millions)	12.3	107.5	20.2	140.0
Area of holding (ha)	(%)	(%)	(%)	(%)
Under 1	16	48	36	43
1–2	13	21	25	21
2–3	11	10	12	11
3–4	7	4	7	5
4–5	6	6	8	6
5–10	12	7	6	7
10–20	13	3	4	4
Over 20	22	1	2	3
Holdings under 5 ha	53	89	88	86

farms as "economic units". The Marxist analysis of the situation states that the remedy lies with structural change in society, in changing the distribution of wealth and allowing the poor to exercise political power. The validity of this analysis is now evident in the total collapse of the Soviet agriculture. But have democratic governments and environments provided more practical solutions? There have been many theories propounded. If you increase the "Gross National Product" poverty will disappear by "trickle down", so GNP becomes the objective and criterion of development. There followed "employment creation and redistribution of wealth" and this was succeeded by the "Basic Needs" policy of the International Labour Organisation (Clayton, 1983).

None of these theoretical approaches, much discussed by the aid agencies, made any difference to the situation but empirical evidence as to the value and importance of the small farmer was growing. Kenya produced vital evidence; the 1972 ILO Employment Mission to Kenya showed that "small farmers, though labour intensive, were far more productive than the large farms." At the same time research into farming systems began to clarify some of the constraints acting on small farmers and demonstrate how the use of farm management systems could overcome some of these.

Farming systems research included social anthropology and began to identify and analyse various levels of social involvement — the farmers family, the village community, the regional group — often based on an ecological background which favours particular cropping systems such as maize/cotton in Kenya — and their interdependence, the whole being modulated by economics, tradition, custom and religion.

The small farmer system, the classic form of which exists with many variations all over the world, has evolved over hundreds of years to maximise survival and relies on the efficient use of all local natural resources, including people. Socio-culturally one of the most important institutions produced by this evolutionary process is the "extended family" which is a type of unitary welfare state which produces the equivalent of unemployment benefit, health services and geriatric care for those members who are ill or aged. The last remnant of this system disappeared in Britain as recently as the 1930s but continues in much of the poorer countries of the world. I have often thought that if a recent British prime minister could experience the system in Africa during her retirement she might well retract one of her more famous sayings that "there is no such thing as society".

But important as the "extended family" system has been to the stability of small farmer regimes, there is a price to pay for this, because it operates strongly against change, innovation and risk taking. This might be a heavy price to pay in our current context because agricultural development clearly demands change and innovation (Clayton, 1983). In pest control this is obvious; changes of climate, of crop variety, of husbandry methods can produce very rapid changes in the pest complex. One has only to think, for example, of the emergence of the brown plant-hopper, *N. lugens* as a major pest of irrigated rice as a rapid consequence of the introduction of high yielding rice varieties (Litsinger, 1989) or the increase in stem borer infestation in farming systems which allow continuous cultivation of cereals.

The small farmer system is designed to retain stability in the face of inimical changes in climate, the economic situation and to ward off poverty. If the price of this is continuation of traditional systems, eventually the stability will break down as the environment changes. This is what has happened in much of Africa where forces of change far greater than those which moulded the system are now at work as outlined above. If therefore, we need to introduce change — and in a sense that is what this symposium is all about — we have to be able to demonstrate that the changes are practical and economically sound, otherwise they are bound to be rejected. If we are to get large communities to operate IPM systems we have to show they work on the relevant scale. Of course this is not the whole story by any means and we shall be hearing much more about these problems in the rest of this symposium. But I am convinced that we need more research on the interaction of socio-cultural factors and farming practice and techniques and I will give some examples of this later.

Meanwhile, let me add one more major factor to the background to this symposium. This can be summed up in the phrase "environmental concern" and I hardly need say more to this audience. Everywhere nowadays — in scientific and political debate— the green phrases ring out— stop the pollution, conserve the environment, save the wildlife, grow it organically. Those of us who are unwise enough to admit publicly to being applied entomologists are castigated as disciples of one of the worst offenders, the agro-chemical industry. This is not the time or the place to review all the arguments but merely to state that the compromise —but best—solution is the IPM one, the only one which ensures reduction in pesticide usage while maintaining sustainable agriculture. However, it cannot be too strongly emphasised that there will be a need for pesticides in IPM systems for the forseeable future and there is an urgent need for further research on the safe use of pesticides by small farmers (Haskell, 1977).

That is why I am glad that ICIPE has put so much effort into this type of work in an African context, especially in mixed cropping and in the animal and public health field. I think pride of place here must be conceded to the control of tsetse fly, for years the scourge of farmers over vast areas of Africa. When I first visited Kenya in 1955 I was amazed at measures such as "tsetse road blocks". Twenty-five years later an environmentally safe and relatively cheap method of control has been perfected, in which ICIPE played a very important part, and the community response and involvement, which we shall hear about in a later session, has been tremendous. We shall hear also of progress with control of other insect vectors of human and animal disease all of which require community involvement.

On the crop side ICIPE work on the effect of resistant varieties and biological control by the natural enemy complex is one of the important lines to pursue but here again there are hidden problems even with biological control and we shall be hearing from Dr. Moore of the International Institute of Biological Control about these later.

One of the IPM techniques best suited to small farmer use is cultural control and I feel that ICIPE should do more work on this. Look at these figures of possibly the simplest of all techniques—mulching—the results of experiments on Kenya coffee carried out in what was then the East African Agricultural and Forestry Research Organisation and is now KARI (Table 3) (Pereira & Jones, 1965).

Table 3. **Coffee yields and gross margins showing response to grass mulches**

Year	Annual rainfall (in)	Control (no mulch)	Mulched all rows (cwt clean coffee)	Mulched alternate rows
1950	24	0.76	1.52	1.09
1951	54	6.81	12.08	10.58
Gross margin K£		287	566	487

Grass mulching of all rows almost doubled the yield and in the dry year 1950 saved the crop from extinction. This seems 100% beneficial, but if we look at other cultural control practices we find some hidden problems. For example, take the technique of altering planting dates so the crop misses the peak infestation period of a particular pest; alteration of sowing dates changes crops yield — often considerably. Look at Table 4, which shows percentage of optimum yield of cotton and you see that even 2 weeks delay reduces yield to 80% — a loss of 20%(Rushton, 1962). Clearly a bad decision in some cases; but in small farmer systems in Kenya, where maize/cotton is a traditional cropping system, the tendency in the extended family system will be to give priority to the food crop because of the family security this gives. This means all labour will be used on the maize, hence cotton planting may be delayed anyhow, with consequent loss of yield. Thus the practical application of IPM techniques has to be worked out with the farmer and that is the case with the ICIPE programme. Hence the importance, for example, of survey of farming households in Kendu Bay and Oyugis divisions in Western Kenya, carried out by Professor Saxena and his ICIPE team, which showed that many farmers lacked basic knowledge of even simple cultural control techniques. This survey also brought out the problem of "area-wide management" — for example the need for synchronous planting of one variety of a crop over a wide area for maximum benefit.

***Table 4.* Effects of delayed sowing on yield of cotton (percentage of yield from that of optimum sowing date)**

Country	Delay in sowing in weeks			
	2	4	6	8
Uganda				
CRS (average of 10-year trials)	81	70	65	39
Serere (average of 10-year trials)		69		42
Serere (average of 10-year trials)	74	54	52	
Kenya				
(Average of 4-year trials)		59		48
(Average of 4-year trials)		37		23
(Average of 4-year trials)		60		47
Tanganyika				
Lake Province		90		74
Lake Province		83	40	26
Lake Province			82	53
Eastern Province		59		
Eastern Province		47		
Eastern Province		53		
Eastern Province		41		22
Nigeria				
(3-year average)	95	56	8	5
(3-year average)	92	67	54	
Average	86	60	50	38
% Loss	14	40	50	62

Other research in IPM systems e.g. rice in the Philippines (Litsinger, 1989) and cotton in Texas under the Econocot programme, (Adkisson *et al.*, 1981), suggests that synchronous planting of the same variety over a large area can produce high yields and reduces some pest problems. In small farmer practice, bearing in mind the very small area of holdings, this could mean getting agreement of hundreds of farmers and this is where community motivation and collaboration is so important and indeed essential, and of course such requirements have led often to setting up of cooperatives, another aspect of community involvement. In fact, as soon as you begin to consider the ecological requirements of a stable cropping system — a basic requirement for successful IPM systems — it becomes obvious that it is important to think about developing systems which are big enough to confer the benefits of a sustaining ecosystem but one which is not so big as to reduce small farmer independence and cause problems of land tenure and local politics and which are too big to administer.

I see here the basis for a new multi-disciplinary research project in ICIPE, with several strands:

1. A basic research element investigating new and environmentally safe methods of control for the pest and disease of a chosen multi-cropping system, which would include basic ecosystem research.

2. An applied research element looking at the practical utilisation of these basic tools in the cropping system, which would naturally include the socio-cultural and socio-economic aspects and also disciplines such as agronomy.

3. A "systems" group which would develop the IPM approach and develop technology transfer methods to assist the teaching and training of small farmers and also develop the necessary research management skills required to run such a large scheme. Of course such multi-disciplinary approaches are not new. However, when one analyses the reasons for their failure in many cases this comes down to a database which is insufficient, not only in science, but in all relevant aspects, to provide a firm foundation for the project. Such projects need to link science and agriculture — and they need a third input as well — industry. There is not much point in producing a lot of high quality maize or cotton unless someone will buy it and use it. Odhiambo (1990), while discussing necessary prerequisites for the development of African agriculture, specifically noted the need for "the systematic linkage and interfacing of the national agricultural research system with the national agricultural productive and industrial sector".

The same requirement has been noted and acted on elsewhere; in 1989 the Directorate for Science Research and Development of the European Community announced a new programme "ECLAIR" — "European Collaborative Linkage between Agriculture and Industry through Research" — to achieve precisely this purpose. We in Cardiff are actually running one of these ECLAIR projects. A consortium of departments in the University of Wales took the lead in developing a proposal with laboratories, government research institutes and commercial firms in Spain, Greece and Italy on "The development of environmentally safe pest control system for European olives". I am the co-ordinator of this project which brings together the work of eleven organisations in the four countries. We have just finished our first year and have already reached the conclusion that the only way forward is to set up a computer linkage system on which to build the essential database, pest forecasting systems and technology transfer developments which will fulfill our objectives. I mention this because I have been struck by the fact that ICIPE already possesses most of the elements required for an approach to link science, agriculture and industry — and this seminar actually covers in some detail very many of the aspects required for an "ECLAIR" type project.

Thus we begin with the foundation of the pest population dynamics and the development of predictive models on which to base practical control programmes. We move on to the basic science required to produce new and environmentally safe control techniques — biological control, natural enemy manipulation, semio-chemicals, microbial pesticides — all active parts of the ICIPE research programme. We move to strategic problems, area-wide information linkage and research management — where ICIPE has PESTNET. What is lacking is industrial partnership and that is an area of considerable importance which must be brought in to complete the picture. In Europe what brings industry into a contractual relationship with universities and research institutes and farmers in the ECLAIR programme is the chance to update their own techniques by using the new knowledge generated by the project and their contractual right to exploit new knowledge under the collaborative agreements on which the programme is based. This must also be true in Africa and it is time to examine the possibilities of linking industry and agriculture more closely.

At the outset of my talk I painted a gloomy picture of the problems of African agriculture. They are certainly serious and a very big effort is needed to overcome them. One important aspect of this effort will be the development of projects concentrating on helping small farmers to realise their full potential, which is clearly very large, as primary producers. ICIPE has the chance to utilise its staff, its laboratories and above all its knowledge database to make a decisive contribution to this vital task and during the next few days I hope we shall discuss in more detail how we may set about this.

REFERENCES

Adkison, P. S., R. E. Frisbie, J. G. Thomas and G. M. McWhorter (1981). Organisation and implementation of an integrated pest management system. *The Southwestern Entomologist* 6, 279–287.

Clayton, E. (1983). *Agriculture, Poverty and Freedom in Developing Countries*. 277 pp. MacMillan Press, London.

Goodell, G. (1984). Challenges to international pest management research and extension in the Third World: Do we really want IPM to work? *Bull. Ent. Soc. Amer.* 30, 18–26.

Haskell, P. T. (1975). Britain's role in international pest control. *Proc. 8th Br. Insectic. Fungi Conf.* 3, 1059–1067.

Haskell, P. T. (1977). Integrated pest control and small farmer crop protection in developing countries. *Outlook on Agriculture* 9, 121–126.

Litsinger, J. (1989). Second generation insect pest problems on high yielding rices. *Trop. Pest Manage.* 35, 235–242.

Odhiambo, T. R. (1990). Personal communication.

Pereira, H. and D. Jones (1965). Field responses by Kenya coffee to fertilisers, manures and mulches. *Emp. J. Ex. Ag.* 22, 85.

Rushton, D. F. (1962). Effects of delay in sowing cotton. *Misc. Report* No. 2. Dept. of Technical Cooperation, London.

World Bank/FAO (1976). *Small Farms Study* Vol. 1. FAO, Rome.

World Bank (1984). Toward sustained development in sub-Saharan Africa. 102 pp.

Biological Control: An Environmentally Safe Alternative to the Use of Chemical Pesticides

Godwin P. Kaaya

The International Centre of Insect Physiology and Ecology (ICIPE),
P. O. Box 30772, Nairobi, Kenya

SUMMARY

The post World War Two era saw widespread use of chemical pesticides for the control of crop and forestry pests as well as vectors of human and animal diseases. Major increases in crop productivity have occurred during the "era of chemical pesticides" and its achievements are partially responsible for the current food surpluses in many developed countries of the world. In the field of public health, millions of lives have been saved through the use of pesticides in vector control programmes (mosquitoes, tsetse, blackflies, etc).

The overuse of chemical pesticides, however, has led to various problems, including environmental pollution, resistance of pests to chemical pesticides, pest resurgence, secondary pest outbreaks and direct hazards to pesticide applicators and consumers. Furthermore, the escalating cost of pesticides has made them less affordable, particularly in developing countries.

The solution to these problems is the development and adoption of a more ecologically-rational pest management strategy, commonly referred to as Integrated Pest Management (IPM). Biological control is a fundamental component of the IPM approach. This paper briefly discusses the use of different biological control agents such as parasitoids and pathogens as a component of IPM, especially in the tropics.

INTRODUCTION

Recent reports of global increase in pollution and food contamination by chemical pesticides, together with escalating costs of pesticides, have highlighted the need for more cost effective and ecologically-rational strategies for pest control. Biological pest control, which involves the use of living organisms to manage pests, plays a central role in the design of sustainable agricultural systems (Mackauer, 1988). Although biological control has solved many pest problems (Greathead and Waage, 1983; Greathead, 1986), natural enemies of pests remain a largely untapped resource of ecologically-harmonious technology to protect against the ravages of pests. Scientists are responding to this need by intensifying their efforts in biological control.

This paper briefly outlines the problems associated with overuse of chemical pesticides and describes different biological control methods and agents that can be used as an alternative, or in addition to, pesticides, with a view to reducing the pesticide load on the environment.

USE OF CHEMICAL PESTICIDES IN PEST CONTROL

The era of synthetic pesticides began in the 1940s with the introduction of DDT in the market in 1946. This pesticide and others were so successful in controlling pests that additional pesticides were developed and introduced into the market. It is estimated that there are now over 1000 pesticides in the world market (Waiyaki, 1986). The average pesticide use annually has been estimated to be a pound weight for every man, woman and child living on earth (Bull, 1982), and in the USA alone, over one billion pounds are used annually (Vinson and Ridgeway, 1977). The use of pesticides has brought about great increases in food production (Wilson, 1988), as well as in the control of vectors of human and animal diseases (Bull, 1982). However, problems caused by overuse of pesticides have been experienced and these are discussed below.

PROBLEMS ASSOCIATED WITH OVERUSE OF CHEMICAL PESTICIDES

1. **Resistance:** By 1984, there were over 600 recorded cases of pest resistance, 425 species of arthropods, 150 of plant pathogens and 50 of weeds (Wilson, 1988).

2. **Costs:** The average price of common pesticides has increased by over 20% annually since 1970. In the Gezira cotton scheme in Sudan, for instance, the cost from 1966–1980 increased by over 1400% . (Pollard, 1981).

3. **Pest resurgence:** After pesticide application, the population of target pests may explode to levels higher than before application because pesticides kill the pests' natural enemies whose populations, unfortunately, take longer to recover than those of pests. (De Bach, 1974).

4. **Secondary pest outbreaks:** Pesticides may kill large numbers of natural enemies of insects other than the target pests, thus enabling potential pests to increase in number and become serious pests (De Bach, 1974). In addition to the 5000–15,000 known species of insect pests, there are probably 10 times as many insect species which are potential pests (Bull, 1982).

5. **Poisonings:** Cases of acute unintentional pesticide poisoning worldwide have been estimated to range from 834,000–1,528,000 annually with the number of deaths estimated at 3000–28,000 of poisoning cases (WHO, 1986a). Jeyaratnam (1985) however, estimated a much higher annual toll of 2,900,000 cases of poisoning and 220,000 deaths worldwide. About 56% of pesticide poisonings and 72% of pesticide related deaths occur in developing countries (WHO, 1986b).

SOLUTION TO PESTICIDE PROBLEMS

There is now widespread acceptance that IPM is the best control strategy, and probably the only one that can help us to achieve long term goals of increased food production and control of vector-borne diseases in an environmentally-friendly manner. IPM is an excellent example of a biological approach to sustainable agricultural production and is characterised by the manipulation of the environment so as to reduce the population densities of key pests to levels below economic injury levels. The tactics of IPM include the introduction of natural enemies, use of pest resistant crop varieties, modification of the environment to enhance effectiveness of biological control agents, and during emergency outbreaks of pest populations, pesticides are used in a manner that causes minimum disruption of the environment. The remaining section of this paper will discuss different biological control approaches for insect pests. Biological control can be defined as the use of natural enemies such as predators, parasitoids and pathogens, to manage pest populations. The approach to biological control includes environmental manipulation, introduction of exotic natural enemies (classical), and augmentation of natural enemies through inundative or inoculative release.

BIOLOGICAL CONTROL BY ENVIRONMENTAL MANIPULATION

This involves manipulation to maximise the effectiveness of naturally-occurring biological control agents (CIBC, 1988), for example by planting flowering plants around sugarcane fields to provide food for adult parasitoids of stem borers; by strip harvesting of alfalfa to conserve aphid predators; and by growing of ground cover in oil palm fields to provide shelter and food for natural enemies of defoliating caterpillars (Huffaker and Messenger, 1976).

CLASSICAL BIOLOGICAL CONTROL

If a pest or potential pest is accidentally introduced into a new locality, it may become a more serious pest in its new home because the natural enemy complex that suppressed it in its original home is not present. A potential solution is to search for its natural enemies in its original home and to introduce them into the new locality where, once established, they will suppress the pest population. Out of 223 insect species subjected to this method, 120 have been permanently controlled and the success has been greater in tropical countries (De Bach, 1974).

The classic example of early successful classical biological control was the importation in 1888 of the ladybird predator *Radolia cardinalis* from Australia to California, USA, to control the cottony cushion scale, *Icerya purchasi*, which was devastating the citrus industry. An entomologist sent from California to Australia to search for its natural enemies brought 140 ladybird predators which were introduced into California. Within just one year, there was an increase of about 200% in orange production and this predator continues to control the pest (Glass, 1988).

Another more recent example is the control programme against the cassava mealybug *Phenacoccus manihoti* in Africa by the International Institute of Tropical Agriculture (IITA). This cassava pest was first reported in Congo/ Zaire in 1973 and has spread rapidly to 31 out of the 35 countries in the African cassava belt, an area 1.5 times the size of USA, causing up to 80% yield losses. A parasitoid of the cassava mealybug, *Epidinocarsis lopezi*, was imported from

South America, where the cassava mealybug originated, and was introduced into 19 African countries over an area of 1.8 million km². Field studies in Ibadan, Nigeria, have shown that cassava yield increases of up to 2.5 tonnes/ ha can be achieved where cassava mealybug has been controlled by this parasitoid (Herren, 1988).

The International Centre of Insect Physiology and Ecology (ICIPE) has an ongoing project for importation of *Cotesia flavipes* from Pakistan for introduction into various localities in Kenya for the control of *Chilo partellus*, a cereal stem borer of great economic importance. Except for *C. partellus*, which originated from Asia, all the other cereal stem borers of Africa are native species.

AUGMENTATIVE BIOLOGICAL CONTROL

Natural enemies of pests can be applied augmentatively. *Trichogramma*, an egg parasitoid which has been used extensively, and a few pathogens (fungi, bacteria and protozoa) will be discussed as successful examples of augmentative biological control.

Parasitoids: The insects of the family Trichogrammatidae (Hymenoptera) are a large group of minute parasitic wasps which attack eggs of various insects. The best known genera of this family, *Trichogramma* and *Trichogrammatoidea*, are exclusively egg parasites, primarily of Lepidoptera, although certain species also attack eggs of Hymenoptera, Neuroptera, Diptera, Coleoptera and Hemiptera (Sithanantham, 1985). The genus *Trichogramma* consists of 36 species and *Trichogrammatoidea* 20 species and one subspecies (Nagarkatti and Nagaraja, 1977). The earliest known attempt to utilize *Trichogramma* was in 1882 when it was shipped from USA to Canada to control sawfly *Nematus ribesii* Scop. (Baird, 1956). Artificial multiplication and release of this parasitoid became a practical method of sugarcane borer control in Louisiana and Barbados in the early part of this century (Metcalfe and Breniere, 1969). The advantage of using *Trichogramma* for pest control is that it kills the egg stage, thus preventing crop damage by the larval stage.

Trichogramma has been used as an alternative to chemical pesticides e.g. in South India to control the internode borer, *Chilo sacchariphagus indicus* in sugarcane fields where the dense crop canopy prevents effective pesticide application (Sithanantham, 1985). It can also be used as a supplement for reducing insecticide load, particularly in cotton, where large quantities of insecticides are used. Release of *Trichogramma* may suppress low populations of bollworms which allows postponement of insecticide application. Sithanantham *et al.* (1973) reported that release of 20,000 *Trichogramma*/acre/week to control *Chilo indicus* (Kapur) in sugarcane fields protected about 2240 canes and 46,800 internodes per acre from damage. In Taiwan, release of *T. australicum* at 40,000 per acre (2500 – 5000 per week) against sugarcane borers was reported to result in 62% fewer bored stalks and 80% reduction in the number of bored joints (Chen, 1967), whereas in South India, release of *Trichogramma* was reported to result in 62 – 90% parasitism of eggs of *Chilo infuscatellus* and yield increases of 3 tonnes/acre (Seshagiri Rao *et al.* 1956). In experiments conducted at ICIPE near Mbita Point Field Station (MPFS) Western Kenya, in which *Trichogramma* was released in sorghum fields for the control of *C. partellus*, the parasitoid suppressed the pest population by about 90% (Lu Quing Quang —Pers. Comm.)

Among several insecticides screened for toxicity against *Trichogramma*, endosulfan was found to be the least toxic and the parasitoid could be released only 2 days after an endosulfan spray. Furthermore, where parasitoids have been released, a waiting period of 5 – 6 days before an endosulfan spray was adequate to safeguard survival of the developing stages (Sithanantham and Navarajan Paul, 1980). *Trichogramma* can be mass-produced commercially as well as in local cooperatives. In China, it is produced in local communes and is used extensively for the control of pests such as corn borer, rice leaf roller, sugarcane borer, pine caterpillars and cotton pests (Huffaker, 1977).

Pathogens: Nematodes, fungi, protozoa, bacteria and viruses have all been used successfully in recent years for the control of forestry and agricultural pests as well as vectors of human diseases.

Fungi: In China, the entomogenous fungus *Beauveria bassiana* is produced in communes in media such as wheat bran, rice powder and ground corn stalks at 8–30° C (Optimum 24° C) and over 90% relative humidity. It is used to control corn borers, leafhoppers in rice and tea, pests of pine forests etc. and induces high mortalities (90–100%) when humidity is high (Hussey and Tinsley, 1981). Boverin, a commercial preparation of *B. bassiana* has been used successfully in USSR in combination with reduced doses of pesticides such as Dipterex (Tricholophon) for the control of Colorado potato beetle and the codling moth with mortalities of 85% – 97% (Ferron, 1981). In Brazil, a commercial preparation of *Metarhizium anisopliae* called "Metaquino" has been successfully used for the control of sugarcane borer (Ferron, 1981). In

Indonesia, *M. anisopliae* has also been used successfully for the control of the rhinocerous beetle *Oryctes rhinoceros* by applying 20 gm/m^2 (Munaan and Wikardi, 1986).

Bacteria: The most used bacteria in biological control of insect pests is *Bacillus thuringiensis*. Most varieties of *B. thuringiensis* kill insects by means of crystalline proteinaceous endotoxins formed during sporulation (Bulla *et al.*, 1977). The crystals are biologically inactive, but after ingestion they are broken down by insect digestive juices and proteases into toxic peptides in the insect gut (Fast and Martin, 1980; Luthy *et al.*, 1982). This so-called delta endotoxin is a stomach poison for insect larvae (Federici, 1982), although host spectrum differs with varieties of *B. thuringiensis*, some being specific for Lepidoptera, some for Coleoptera, others for Diptera (Federici, 1982; Luthy *et al.*, 1982). In addition to the δ-endotoxin, *B. thuringiensis* serotype 1 also produces a δ-exotoxin (*thuringiensin*) which is particularly effective against dipterous larvae (Sebesta *et al.*, 1981; Carlberg *et al.*,1985). *B. thuringiensis* serotype H-14 has been used to control larvae of mosquitoes and blackflies (Goldberg and Margalit, 1977; Lacey *et al.*, 1982; Vandekar and Dulmage, 1982), and *B. thuringiensis* serotype 1 has been used to control house fly larvae in latrines (Carlberg *et al.*, 1985; Carlberg, 1986).

Several commercial preparations of *B. thuringiensis* var *israelensis* (*Bti*) e.g. Bactimos, Teknar, Vectobac, Skeetal, Bacidor and Moskitur are in the market and have been used extensively for the control of mosquito and blackfly larvae. Many formulations such as wettable powders, liquid concentrates, granules, pellets, tablets and floatable briquets are used in routine treatment of breeding sites. In the Upper Rhine valley where mosquitoes such as *Aedes vexans*, *Ae. sticticus* and *Ae. rossiens* are serious nuisance, *Bti* preparations have been used very successfully to control mosquitoes in over 90% of the approximately 300 km of the river (Becker, 1990). In the *Onchocerciasis* control programme in West Africa, larvae of *Simulium damnosum* have developed resistance to the organophosphate Temephos which has been in use since 1974. As an alternative, *Bti* is being used and has proved to be very effective. Thousands of river kilometres in the Volta river basin in 11 countries are treated with more than 700,000 litres of *Bti* liquid concentrate annually (Davidson, 1989).

In China, *B. thuringiensis* is produced on a large scale in the communes by two techniques, solid and liquid fermentation, and is used against several pests such as paddy borer, armyworm, leaf-roller, rice-skipper, tea tussock moth, diamond-backed moth and cotton bollworm (Hussey and Tinsley, 1981).

Experiments conducted at ICIPE have shown that larvae of *C. partellus* and *Busseola fusca* are highly susceptible to *B. thuringiensis* and that a single application may result in 100% mortality compared to 0 – 5% in untreated controls, while in the screenhouse, an increase of 5 – 7 times in sorghum yield was achieved in the *B. thuringiensis* treated compared to untreated crop (Brownbridge, 1989).

Both commercial and local Kenyan isolates of *B. thuringiensis* have also been tested in the field against natural outbreaks of the African armyworm *Spodoptera exempta* and high levels of control were achieved. Using a 2% w/v suspension, 90–95% larval mortality was achieved within 48 hrs, post-application (Brownbridge, 1988,1989). In field experiments conducted at Mtwapa on the Kenya coast to evaluate the efficacy of a local *B. thuringiensis* isolate for *Chilo* control in maize, the treated plots yielded over 600 kg/ha more maize seed than untreated control plots indicating that *B. thuringiensis* is an effective biopesticide for *Chilo* control (Brownbridge, 1990).

Protozoa: *Nosema locustae* has been shown to be effective for the contról of grasshoppers and crickets (Henry and Oma, 1981). At ICIPE, a *Nosema* sp. originally isolated from *Maruca testulalis* has been shown to be effective against the cereal stem borer *C. partellus*. Sorghum infested with *C. partellus* larvae and treated with *Nosema* exhibit significant reductions in foliar damage (87.5% at 24 days post-application), dead heart formation (60%) and a significant increase (80%) in yield of seed compared to control plots (Odindo, 1991). More recent experiments conducted at ICIPE and Mtwapa on the Kenya coast, revealed that this protozoan may be as effective as a chemical pesticide (Dipterex) for *Chilo* control (Odindo—Pers. Comm.).

Viruses: In recent years, several entomopathogenic viruses have been isolated, evaluated and developed for the control of forest and agricultural pests. For instance, the nucleopolyhedrosis virus (NPV) *Baculovirus heliothis* has been used successfully for the control of *Heliothis* species in cotton, maize, sorghum and soybeans, and in most cases it was found to be as effective as chemical pesticides (Ignofo and Couch, 1981). The virus has been commercialised and is sold under the name "Elcar" and its development costs were 2 to 5 times cheaper than those estimated for a chemical pesticide (Ignofo and Couch, 1981). Gypsy moth, *Lymantria dispar*, an important forest pest in central Europe and the USA has also been successfully controlled by a baculovirus which is now marketed under the name "Gypchek" (Lewis, 1981). A baculovirus preparation has been extensively used to control the European pine sawfly, *Neodiprion sertifer* in several countries (Cunningham and Entwistle, 1981).

The baculovirus of the rhinoceros beetle *Oryctes rhinoceros*, has been successfully used for the control of the beetle, a serious pest of coconut and oil palms. Adult beetles are trapped, infected in the laboratory using a mixture of sawdust and ground larvae containing the virus, and then released to contaminate breeding sites and palm crowns, spreading the virus into the wild population (Bedford, 1981). Such releases of infected adult beetles in Indonesia resulted in a steady recovery of infested palm trees (Munaan and Wikardi, 1986). In Mauritius, the virus was applied in manure heaps in 1970–1972 and reduced the mean number of larvae per heap from 24 in 1970 to 4 in 1976/77, and damage to palms by 60–95%, although no more virus was released since 1972 (Bedford, 1981).

Nematodes: Entomogenous nematodes have a wide spectrum of action, do not infest vertebrates or plants, persist at low levels in natural habitats and are effective against insects in cryptic habitats (Hominick, 1990). One of the limitations of nematodes as a biocontrol agent, however, is their requirement for moist environment and therefore dessication can be a serious limiting factor in dry areas. Nematodes have been used for the control of various forest and agricultural pests. *Neoaplectana carpocapsae*, has been reported to be effective against several agricultural pests such as tobacco budworm, the codling moth, cut worm etc. (Poinar, 1979).

CONCLUSION

This paper discusses the hazards associated with use of chemical pesticides and presents ecologically-rational alternatives. *Trichogramma* has been used extensively in developed as well as in some developing countries. The methods of production and application are not sophisticated and can therefore be used to replace chemical pesticides in developing countries, or at least to reduce the amount of pesticides required to control pests. Although it has been claimed that tropical areas may not be very suitable for some biological control agents, such as viruses, due to high solar radiation, tropical regions have an advantage when it comes to pathogens such as entomopathogenic fungi, which require a warm climate and high humidity (Hall and Payne, 1986). As mentioned earlier, fungi and bacteria such as *B. thuringiensis* can be mass-produced fairly cheaply, and since no ingredients are imported, the final product will be inexpensive, thus saving developing countries on foreign currency used for importing chemical pesticides. Moreover, the possibility of deterioration during shipment from one country to another is avoided with locally-produced biopesticides (Hall and Payne, 1986).

Most of the developing countries are located in the tropical and sub-tropical regions, which are not yet saturated with chemical pesticides and hence the chances of success of classical biological control may be higher than in developed countries (Wilson, 1988). For pest control techniques to be accepted by farmers, it is important that they are involved right from the start. Thus scientists at ICIPE conduct their biological control evaluation experiments directly in farmers' fields so that farmers are partners in the development of such techniques. Most of the biological control agents take several days or weeks to kill pests compared to chemical pesticides which take only seconds or a few minutes. Farmers who can afford chemical pesticides may therefore be reluctant to adopt biological control methods. Training of farmers in the benefits of biological control, including environmental conservation and avoidance of pest resistance is therefore of paramount importance.

Over the last four years the Biological Control Sub-Programme (BCSP) at ICIPE has trained several different levels of biological control personnel. Training workshops for technical staff working in national programmes in various African countries have been organised, while some technicians from national programmes have visited ICIPE for periods of 2–3 months to train in biological control techniques. The BCSP has also trained over 27 post-graduate (Ph.D. and M.Phil.) trainees from 10 African countries over the last 4 years. Occasionally, open days during which farmers are invited to visit ICIPE research fields are organised to allow them to see our techniques and results.

Further research on isolation, identification and evaluation of indigenous biological control agents in developing countries is required and this should continue simultaneously with training manpower in biological control techniques. Only in this way, will developing countries be able to develop environmentally-friendly, economically-affordable sustainable pest control methods.

REFERENCES

Baird, A. B. (1956). Biological Control. In *Entomology in Canada up to 1956: A Review of Developments and Accomplishments*, pp. 363–367, (Ed. R. Glenn).

Becker, N. (1990). Microbial control of mosquitoes and black flies. *Proc. Invert. Pathol. Colloq*. Adelaide, Australia, pp. 84–89.

Bedford, G. O. (1981). Control of the rhinocerous beetle by baculovirus. In *Microbial Control of Pests and Plant Diseases, 1970–1980*, pp. 409–426, (Ed. H. D. Burges), Academic Press, London, New York, Toronto, Sydney, San Francisco.

Brownbridge, M. (1988). Evaluation of *Bacillus thuringiensis* for control of *Chilo partellus*. *ICIPE Annual Report*, No. 16, 17–18.

Brownbridge, M. (1989). Further evaluation of *Bacillus thuringiensis* for the control of lepidopteran pests. *ICIPE Annual Report*, No. 17, 14–15.

Brownbridge, M. (1990). Continuing research on the control of cereal stem borer spp with *Bacillus thuringiensis*. *ICIPE Annual Report*, No. 18, 38–39.

Bull, D. (1982). A growing problem: Pesticides and the third world poor. Oxfam, Oxford OX2 7d2.

Bulla, L. A., Jr., K. J. Kramer and L. I. Davidson (1977). Characterization of the entomocidal parasporal crystal of *Bacillus thuringiensis*. *J. Bacteriol.* 130, 375–382.

Carlberg, G. (1986). *Bacillus thuringiensis* and microbial control of flies. *Mircen J.* 2, 267–274.

Carlberg, G., C. M. Kihamia and J. Minjas (1985). Microbial control of flies in latrines in Dar-es-Salaam with a *Bacillus thuringiensis* (serotype I) preparation. *Muscabac. Mircen J.* 1, 33–44.

CIBC (1988). Priorities for biological control of insect pests and weeds in tropical Africa, 1–36.

Chen, C. B. (1967). The biological control of sugarcane borers in Taiwan 1948–1966. *Mushi* 39, 103–108.

Cunningham, J. C. and P. F. Entwistle (1981). Control of sawflies by baculovirus. In *Microbial Control of Pests and Plant Diseases, 1970–1980*, pp 379–407, (Ed. H. D. Burges), Academic Press, London, New York, Toronto, Sydney, San Francisco.

De Bach, P. (1974). *Biological Control by Natural Enemies*, Cambridge University Press.

Davidson, W. (1989). Microbial control of vector insects. *VCLA Symposium on Molecular and Cellular Biology*, Vol. 112.

Ebersold, H. R., P. Luthy and M. Mueller (1977). Changes in the fine structure of the gut epithelium of *Pieris brassicae* induced by the δ-endotoxin of *Bacillus thuringiensis*. *Bull. Soc. Entomol. Suisse* 50, 269–276.

Fast, P. G. and W. G. Martin (1980). *Bacillus thuringiensis* parasporal crystal toxin: Dissociation into toxic low molecular weight peptides. *Biochem. Biophys. Res. Commun.* 95, 1314–1320.

Federici, B. A. (1982). Site of action of the δ-endotoxin of *Bacillus thuringiensis* in mosquito and blackfly larvae. In *Basic Biology of Microbial Larvicides of Vectors of Human Diseases*, pp. 37–47, (Ed. F. Michal), UNDP/ World Bank/WHO Special Programme for Research and Training in Tropical Diseases, Geneva.

Ferron, P. (1981). Pest control by the fungi *Beauveria* and *Metarhizium*. In *Microbial Control of Pests and Plant Diseases, 1970–1980*, pp 465–482, (Ed. H. D. Burges), Academic Press, London, New York, Toronto, Sydney, San Francisco.

Glass, E. (1988). CGIAR: Biological Control of Cassava Pests in Africa, pp 1–16, 1987/88. *Annual Report*.

Goldberg, L. J. and J. Margalit (1977). A bacterial spore demonstrating rapid larvicidal activity against *Anopheles sergentii, Urantaenia unguiculata, Culex univittatus, Aedes aegypti* and *Culex pipiens*. *Mosq. News* 37, 355–358.

Greathead, D. J. and J. K. Waage (1983). Opportunities for biological control of agricultural pests in developing countries. *World Bank Technical Paper* No. 11, 44.

Greathead, D. J. (1986). Opportunities for biological control of insect pests in tropical Africa. *Revue de Zoologie Africaine* 100, 85–95.

Hall, R. A. and C. C. Payne (1986). Potential of insect pathogens in the tropics In *Biological Control in the Tropics*, pp 187–196, (Eds. M. Y. Hussein and A. G. Ibrahim).

Henry, J. E. and E. A. Oma (1981). Pest control by *Nosema locustae*, a pathogen of grasshoppers and crickets. In *Microbial Control of Pests and Plant Diseases 1970–1980*, pp 573–580, (Ed. H. D. Burges), Academic Press, London, New York, Toronto, Sydney, San Francisco.

Herren, H. R. (1988). The biological control programme of IITA: From concept to reality. In *Biological Control — A Sustainable Solution to Crop Pest Problems in Africa*, pp 18–30, Proc. inaugr. conf. wksh., IITA B.C. prog. centr. Afr., Dec. 5–9, (Eds. J. S. Yaninek and H. R. Herren), IITA, Ibadan, Nigeria.

Hominick, W. M. (1990). Entomopathogenic rhabditid nematodes and pest control. *Parasitol. Today* 6, 148–152.

Huffacker, C. B. and P. S. Messenger (1976). *Theory and Practice of Biological Control.* New York, Academic Press.

Huffacker, C. B. (1977). Augmentation of natural enemies in the People's Republic of China. In *Biological Control by Augmentation of Natural Enemies*, pp 329–339, (Eds. R. L. Ridgeway and S. B. Vinson), Plenum Press, New York and London.

Hussey, N. W. and T. W. Tinsley (1981). Impressions of insect pathology in the People's Republic of China. In *Microbial Control of Pests and Plant Diseases, 1970–1980*, pp 785–795, (Ed. H. D. Burges), Academic Press, London, New York, Toronto, Sydney, San Francisco.

Ignofo, C. M. and T. L. Couch (1981). The nucleopolyhedrosis virus of *Heliothis* species as a microbial insecticide. In *Microbial Control of Pests and Plant Diseases, 1970–1980*, pp 329–362, (Ed. H.D. Burges), Academic Press, London, New York, Toronto, Sydney, San Francisco.

Jeyaratnam, J. (1985). Health problems of pesticide usage in the Third World. *Brit. J. Indust. Med.* 42, 505–506.

Lacey, L. A., H. Escaffre, B. Philippon, A. Seketeli and P. Guillet (1982). Large river treatment with *Bacillus thuringiensis* (H-14) for the control of *Simulium damnosum* s.l. in the Onchocerciasis Control Programme. *Tropenmed. Parasitol.* 33, 97–101.

Lewis, F. B. (1981). Control of the gypsy moth by a baculovirus. In *Microbial Control of Pests and Plant Diseases, 1970–1980*, pp 363–377, (Ed. H.D. Burges), Academic Press, London, New York, Toronto, Sydney, San Francisco.

Luthy, P., F. Jaquet , H. E. Huber-Lukac and M. Huber-Lukac (1982). Physiology of the δ-endotoxin of *Bacillus thuringiensis* including the ultrastructure and histopathological studies. In *Basic Biology of Microbial Larvicides of Vectors of Human Disease*, pp 29–36, (Ed. F. Michal), UNDP/ World Bank/WHO Special Programme for Research and Training in Tropical Diseases, Geneva.

Mackauer, M. (1988). Biological control in the context of systems management. In *Biological Control— A Sustainable Solution to Crop Pest Problems in Africa*, pp 68–83, Proc. inaugr. conf. wksh., IITA, B.C. prog. centr. Afr., Dec. 5–9, (Eds. J. S. Yaninek and H. R. Herren), IITA Ibadan, Nigeria.

Metcalfe, J. R. and J. Breniere (1969). Egg parasites (*Trichogramma* spp.) for the control of sugarcane borers. In *Pests of Sugar Cane*, pp 108–115, (Eds. J. R. Williams *et al.*), Elsevier, Amsterdam.

Munaan, A. and E. A. Wikardi (1986). Towards the biological control of coconut insect pests in Indonesia. In *Biological Control in the Tropics*, pp 149–157, (Eds. M. Y. Hussein and A. G. Ibrahim).

Odindo, M. O. (1991). Management of cereal stem borers, especially *Chilo partellus*, using microsporidia. *Insect Sci. Applic.* 12, 51–55.

Pollard, N. (1981). The Gezira Scheme — A study in failure. *The Ecologist*, pp 155–157, CRC Press, Inc.

Poinar, G. O. (Jr) (1979). *Nematodes for Biological Control of Insects*. pp155–157, CRC Press, Inc.

Sebesta, K., J. Farkas, K. Horska and J. Vankova (1981). *Thuringiensin*, the β-exotoxin *Bacillus thuringiensis*. In *Microbial Control of Pests and Plant Diseases, 1970–1980*, (Ed. H. D. Burges), pp 249–281, Academic Press, London, New York, Toronto, Sydney, San Francisco.

Seshagiri Rao, D. S., M. Puttarudriah and K. S. S. Sastry (1956). Biological control of sugarcane borers in Mysore — a brief review of work done in regard to the production and liberation of *Trichogramma evanescens minutum* R. in Mysore, pp 1–13. Proc. 9th Cong. Int. Soc. Sug. Techn., India.

Sithanantham, S. (1985). Utilization of trichogrammatid parasites —Problems and prospects with special reference to India. ICAR National Biocontrol Workshop, Coimbatore, Tamil Nadu, India, 13–16 September.

Sithanantham, S., S. Muthusamy and R. Durai (1973). Experiments on the inundative release of *Trichogramma australicum* Gir. in the biological control of sugarcane stemborer, *Chilo indicus* Kapur. *Madras Agric. J.* 60, 457–461.

Sithanantham, S. and A.V. Navarajan Paul (1980). Toxicity of some insecticidal sprays to the parasitoid, *Trichogramma australicum* Gir. (Hymenoptera: Trichogrammatidae). *Pestology* 4, 21–24.

Vandekar, M. and H. T. Dulmage (1982). Present status of *Bacillus thuringiensis* H-14 and its proposed use in disease control programmes. In *Guidelines for Production of* Bacillus thuringiensis *H-14*, pp 7–18, UNDP/World Bank/ WHO Special Programme for Research and Training in Tropical Diseases, Geneva.

Vinson, S. B. and R. L. Ridgeway (1977). Preface — In *Biological Control by Augmentation of Natural Enemies*, V–IX, (Eds. R. L. Ridgeway and S. B. Vinson), Plenum Press, New York, London.

Waiyaki, B. C. (1986). International efforts to promote environmentally-sound pest management: Role of UNEP. In *Biological Control in the Tropics*, pp 1–14, (Eds. M.Y. Hussein and A. G. Ibrahim).

WHO (1986a). Informal consultation on planning strategy for the prevention of pesticide poisoning. WHO/VBC/86. 926.

WHO (1986b). Assessment of mortality and morbidity due to unintentional pesticide poisonings. WHO/VBC/86. 929.

Wilson, L. (1988) Introductory remarks on the chair. In *Biological Control — A Sustainable Solution to Crop Pests Problems in Africa*, pp 1–4, Proc. inaugr. conf. wksh. IITA B.C. prog. centre. Afric., Dec. 5–9, (Eds. J. S. Yaninek and H. R. Herren), IITA Ibadan, Nigeria.

The Role of Models in Integrated Pest Management for Resource-Poor Farmers

R. W. Sutherst

CSIRO Division of Entomology
Cooperative Research Centre for Tropical Pest Management
Gehrmann Laboratories, University of Queensland
Brisbane, Queensland, Australia 4072

SUMMARY

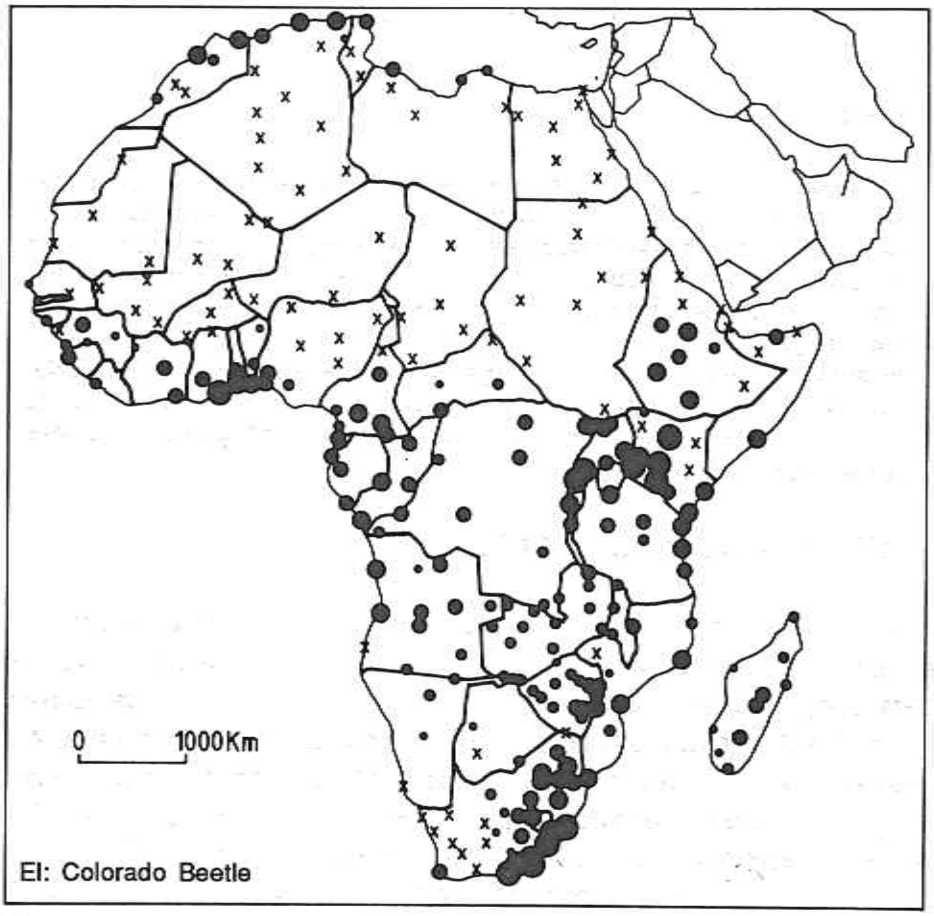
There are several questions which always need to be asked in relation to crop pest management. We need to know where the pests occur, when they occur, how many there are at different times, what their population dynamics are like, what their behaviour is, what economic damage they cause, and what are the most profitable and sustainable management strategies to reduce their impact on agriculture. Many of these questions are amenable to application of modelling or expert systems approaches. In this paper, a brief review is given of the type of approach that can be taken to each of those questions which are relevant to both commercial IPM and to pest management for resource-poor farmers.

1. WHERE CAN PESTS OCCUR?

The potential geographical distribution of insect pests depends principally on climate, but host availability and the pest's ability to disperse naturally or be dispersed by human assisted means also limit their ranges. Databases and geographic information systems (GIS) can be used to answer some of these questions. However, as climate is so variable from place to place, some form of computer-based information system is needed to cope with the spatial and temporal aspects of climate. Appropriate models need to be able to display spatial distributions of different climatic conditions and to be able to indicate seasonality of favourable and unfavourable conditions. The underlying causes of these conditions need to be identified for each species. In addition, the models have to be able to be coupled in some way to other information on non-climatic variables.

The PESKY/CLIMEX combination of models can address such a problem (Sutherst *et al.*, 1991). PESKY is an expert system which can obtain information from various sources such as the CLIMEX climate-matching model, pest population models, (GIS) with geographically based databases, users with local knowledge and other computer databases as required.

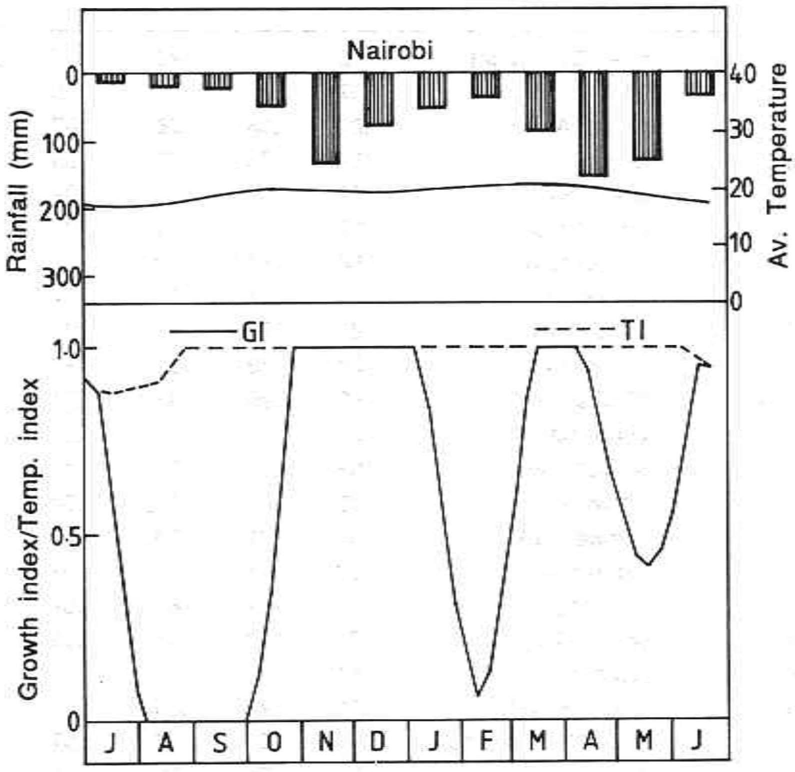
Fig.1. **The area of Africa at risk of colonisation by the Colorado beetle, *Leptinotarsa decemlineata*, as estimated using the CLIMEX model. Areas of the circles are proportional to the suitability of the climate for permanent occupation by the beetle**



CLIMEX

The major uses of CLIMEX to date have been in biogeography, population ecology, quarantine, biological control, and evaluation of impacts of climate change. Many of the uses under these categories have been documented in the literature. As an illustration of its use in quarantine, the risk posed to Africa by the Colorado beetle is illustrated in Fig. 1. It is clear that a large part of Africa is at risk from this very costly pest. In a more focused way, it is possible now to concentrate in more detail on particular countries such as Kenya and even on a particular town such as Nairobi. The climatic suitability of Nairobi is illustrated in Fig. 2.

Fig. 2.* The seasonal climatic suitability of Nairobi for the Colorado beetle, *Leptinotarsa decemlineata*, as estimated using the CLIMEX model. The growth index (GI) indicates the weekly favourableness of the climate for population growth, while the temperature index (TI) describes the species' response to temperature *per se



GI = 58 EI = 58

If a pest is causing problems CLIMEX can assist in targeting biological control. In such an event the search for possible natural enemies can be based on matching the climate of the target area, such as Kisumu, with other parts of the world from where the pest may have been introduced. This facility (Table 1) allows much more cost-effective targeting of collection sites for biological control agents and increases the chances of successful establishment of those agents on introduction into the new environment. In this particular example the results emphasise the uniqueness of the East African climate, with few locations in other continents with similar climates. More detailed investigation of the species' response to climate, such as that above, is indicated if a promising target area is not identified in the continent of origin of the pest targeted for biocontrol.

Table 1. **Results of a CLIMEX search for global locations with climates most similar to Kisumu, for use in searching for climatically adapted biocontrol agents**

		Match Index	Max. Temp.	Min. Temp.	Total Rain	Rain Pattern
Noumea	(New Caledonia)	.75	.80	.76	.97	.75
Havana	(Cuba)	.67	.82	.59	.93	.68
Cape St. Lucia	(South Africa)	.67	.66	.76	.87	.72
Rio De Janeiro	(Brazil)	.67	.73	.75	.95	.64
Bridgetown	(Barbados)	.65	.80	.51	.89	.72
Lady Elliot Island	(Queensland)	.65	.66	.66	.97	.66
Sandy Cape	(Queensland)	.64	.66	.72	.89	.67
Quissico	(Mozambique)	.64	.87	.77	.84	.59
Heron Island	(Queensland)	.64	.71	.65	.91	.66
North Reef	(Queensland)	.64	.73	.63	.93	.64
Yaounde	(Cameroon)	.63	.80	.85	.71	.68
Zamboanga	(Philippines)	.63	.64	.45	.94	.77
Lomie	(Cameroon)	.63	.83	.88	.70	.66
Souanke	(Congo)	.62	.82	.88	.64	.71
Moloundou	(Cameroon)	.62	.71	.70	.73	.74
Corrientes	(Argentina)	.62	.61	.63	.97	.64
N'dalatondo	(Angola)	.61	.81	.86	.92	.49
Easter Island	(Easter Island)	.61	.49	.81	.83	.69
Bustard Head	(Queensland)	.61	.61	.69	.98	.58
Maryborough	(Queensland)	.61	.72	.55	.96	.60
Casino	(New South Wales)	.60	.69	.49	.97	.64
Conception	(Bolivia)	.60	.79	.76	1.00	.47
Wau	(Papua-New Guin.)	.60	.92	.80	.59	.72
Toalanaro	(Madagascar)	.60	.75	.78	.67	.71

The conclusions reached in relation to the use of the CLIMEX model are firstly, that there is a need for information systems in quarantine and biological control. Secondly, potential geographical distributions of pests and biocontrol agents are predictable to a large degree. Thirdly, climatic and non-climatic information systems need to be linked using expert system-type packages, and those packages need to be made user-friendly for application by biologists with a limited amount of specialist knowledge of either particular pests or of computers.

2. WHEN AND HOW MANY PESTS?

The seasonal incidence and total numbers of pests of different species vary greatly over geographical zones. These are a function of variable development, fecundity or mortality rates. In addition, the effects of density dependent factors, which tend to damp some of those fluctuations, need to be accounted for. In order to understand the seasonal dynamics of pest numbers, it is necessary to isolate each of these variables in order to investigate the contribution made by each to the total observed variation. For example, the effect of variable development rates *per se* proved useful in setting priorities for allocation of effort in the screwworm fly, *Cochliomyia hominivorax*, eradication programme in Tripoli, Libya (Floyd *et al.*, 1991). Similarly, a model of tsetse fly, based on relating mortality rates to local climograms, has been described by Rogers and Randolph (1986). It has application in areas where there is limited annual variation in temperature and hence fairly constant development rates. Comprehensive population models need to incorporate all important variables in a pest's life system. Examples of such models include Gutierrez *et al.*, (1974), Sutherst *et al.*, (1979).

3. ECONOMIC DAMAGE

The economic threshold, above which it is profitable to control a pest, depends upon the value of the product, and the nature and extent of the damage caused by a particular pest. These relationships can either be quite straightforward in the case of pests which cause proportional damage with increasing numbers, or they can be quite complicated, as illustrated by the case of ticks and tick-borne diseases (Sutherst & Kerr, 1987). In such a situation the incidence of clinical tick-borne diseases is high when the vector population levels are either low or variable from year to year with breaks in transmission followed by periods of high transmission to non-immune hosts. Superimposed on that is the effect of ticks *per se* which increase linearly with tick numbers. These relationships need to be incorporated into pest management models to transform the pest numbers into economic terms. The models can then be used to evaluate the importance of the damage-pest relationship relative to other variables, such as host resistance, migration rates, etc in determining the most promising management strategy.

4. WHAT TO DO ABOUT PESTS : INTEGRATED PEST MANAGEMENT

Any system of integrated pest management needs the total crop-pest system to be defined. In this way the pest is put into the context of the farming system that it affects. The damage caused by the pest has to be defined, as described above, and different control options have to be evaluated and defined so that they can be used in the most profitable way. Management aspects of the IPM control strategies need to be defined (Norton *et al.*, 1983). Computer simulation models are by far the most efficient way of integrating the effects of damage and control functions to estimate the optimal control strategies. For example, an increasing tick control programme is shown to have declining benefits when excessive levels of control are reached (Floyd *et al.*, 1987).

5. CONCLUSIONS

A range of different types of models are helpful in defining sustainable IPM strategies for resource poor farmers. These include spatial models for quarantine, development rate models to predict the timing of emergence of different cohorts of pests, population dynamics models to estimate population sizes, their seasonality, and the extent of damage caused to the host plant, management models to optimise control options and finally expert systems to provide a means of conveying expert knowledge to advisory staff. Development of each of these approaches can have great heuristic value in addition to being practical tools for IPM.

REFERENCES

Floyd, R. B., J. G. Smillie and R. W. Sutherst (1991). Predicted pattern of emergence of adult New World screwworm fly in Libya in an average year. *FAO/SECNA New World Screwworm Newsletter* 03/91, p 3.

Floyd, R. B., R. W. Sutherst and G. G. Maywald (1987). Modelling tick management. 3. Designing control strategies for *Rhipicephalus appendiculatus* using T3HOST. In *Ticks and Tick-Borne Diseases*, (Ed. R. W. Sutherst), *ACIAR Proc.* No. 17, 141–144 ACIAR, Canberra.

Gutierrez, A. P., D. E. Havenstein, H. A. Nix and P. A. Moore (1974). The ecology of *Aphis craccivora* Koch and subterranean clover stunt virus in South-east Australia. II. A model of cowpea aphid populations in temperate pastures. *J. Appl. Ecol.* 1, 11–20.

Norton, G. A., R. W. Sutherst and G. G. Maywald (1983). A framework for integrating control methods against the cattle tick, *Boophilus microplus*, in Australia. *J. Appl. Ecol.* 20, 489–505.

Rogers, D. J. and S. E. Randolph (1986). Distribution and abundance of tsetse flies (*Glossina* spp.). *J. Anim. Ecol.* 55, 1007–1025.

Sutherst, R. W., G. A. Norton, N. D. Barlow, G. R. Conway, M. Birley and H. N. Comins (1979). An analysis of management strategies for cattle tick (*Boophilus microplus*) control in Australia. *J. Appl. Ecol.* 16, 359–382.

Sutherst, R. W. and J. D. Kerr. (1987). Losses in livestock productivity caused by ticks and tick-borne diseases. In *Ticks and Tick-Borne Diseases*, (Ed. R. W. Sutherst); *ACIAR Proc.* No. 17, 108–112. ACIAR, Canberra.

Sutherst, R. W., G. F. Maywald and W. Bottomley (1991). From CLIMEX to PESKY, a generic expert system for pest risk assessment. Proc. WMO/EPPO/NAPPO symposium on practical applications of agrometeorology in plant protection. *EPPO Bull.* 21, 595–608.

Chemical Signals in Plant vs Insect Interaction

Heinz Rembold

Max-Planck Institute for Biochemistry,
Insect Biochemistry Unit, 8033 Martinsried near Munich, Germany

SUMMARY

A living organism must, for its survival, interact with its environment through different physical, behavioural, or chemical information. Such a signal-mediated strategy of inter-individual communication is called "biosemiotics". As a new paradigm of biology, it is presently only poorly understood. Biosemiotics plays an integral role in ecology and knowing more about this field of signal-controlled interaction will also help in designing better plant protection strategies.

Insects, besides other signals, also make use of species-specific plant metabolites for finding their host. Such compounds are used as distance or as contact-perceivable semiochemicals. Some of them are harmful — as kairomones — and others are useful — as allomones — for the plant. Also the polyphagous herbivore selectively uses them in its host-finding strategy for oviposition and feeding. Our own research concentrates on the identification of such kairomones from grain legumes which attract the female *Heliothis armigera* moth for egg laying and its larvae for feeding. A synthetic chickpea kairomone, composed of the three terpenes delta-3-carene, alpha-pinene, myrcene, and pentan-1-ol in a defined mixture, specifically attracts the mated, egg laying moth and the larvae. Unmated females react poorly to the kairomone and the male *Heliothis* moths are unaffected. Field experiments result almost exclusively in female catches. Malic acid is the main component of the chickpea exudate, it seems to be responsible for *Heliothis* resistance in the chickpea by acting as a contact perceivable signal. Agroclimatic effects on malate concentration of the exudate and consequently the stability of a certain chickpea line under different ecological conditions is discussed as another example of the interconnectedness of field performance in the world of biosemiotics.

All living creatures, from the bacterial cell up to the most complicated mammalian systems, can only survive by being constantly exposed to a world of different signals. Such signals can be a sound or just noise, warmth or coldness, light or darkness, moisture or dryness, fragrance or stink, or even just a magnetic field. These signals induce species-specific and individually modulated behaviour which is controlled by inborn and by adapted behavioural programmes. Many of these signals are unconsciously recognised and consequently are neutral in their effect on the recipient's behaviour. The organism has become used to them and only reacts if they deviate from the standard situation. Charles Baudelaire reflects in a letter that "perfumes, colours, and sounds echo one another" and this comment nicely mirrors the interdependency of very different environmental signals. Through a long evolutionary process each species became adapted to its typical environment and learned to live with the existing signals accordingly. The organism communicates with its world in its own language which for each species has its typical dialect. As in linguistics, where research on semiotics studies how words or phrases are formed according to existing patterns, the semantics of environmental signals can be studied and finally deciphered by a combination of many different fields of specialisation, from mathematics and chaos theory through physics and chemistry to molecular biology.

On this basis, biosemiotics is emerging as a powerful and forward-looking venture that will be able to initiate a paradigm-shift and lead to a new biology as a prospective discipline in its own right (Eder and Rembold, 1991; Rembold and Eder, 1991). Resulting from an emergence-oriented approach, it is a stimulating new perspective for problems like complexity, diversity, interdependence and the role of chaos in biology. Such a complex field can only be approached by the multidisciplinary concept described already. Complexity of an organism results not only from the diversity of its molecular components but primarily from their highly organised interactions. The more the diversity of organisms is explored, the more semiotic relationships will be discovered. As a useful verbalisation, "ethogram" (Seboek, 1968) was suggested to designate the coherent picture of all biosemiotic events and relationships of one species. Because of interdependence, biosemiotics is also relevant to protosemiotics as well as to an emergence-oriented view, to higher levels or integration such as intra- and inter-species relationships. In other words, biosemiotics will tell us how, e.g. a plant communicates with its environment including an insect or, the other way round, how the insect talks to a plant. Biosemiotics has a pronounced bearing on chaos research (Anderson *et al.*, 1984).

Nature appears replete with dynamic systems which are far from equilibrium, made up of interdependent and interacting individuals. The information-processing ability of a biological system or of a whole ecosystem is controlled by a set of signals pertaining to the chaotically free and subtly interacting elements at the next lower level of its hierarchy. Insect sociality may be mentioned as one example which offers a biosemiotic approach. Social behaviour has emerged several times during evolution. Insect societies, however, represent a climax of biological integration. Social organisation is always based on some sort of language mediated communication and honey bees represent the zenith of chemosociality. A large variety of behaviour has been shown to be regulated by pheromonal signals originating from diverse exocrine glands from either worker or queen. Above all, the caste system and the resulting division of labour display a communicative elegance which points to a close linkage between biosemiotic structures and social organisation which is beyond the target-directed function of each individual signal (Wenner, 1968; Rembold, 1987).

In the course of insect-plant coevolution, a number of plants have learnt to protect themselves by means of semiochemicals. Repelling substances in leaf exudates are distance-perceivable or contact signals. By modifying the behaviour of pest insects they act as resistance factors and contribute to a partial protection of the host plant. The emergence of kairomones as host-plant fingerprints on the other hand was a significant achievement for the benefit of the insect. Plant volatiles as olfactory cues are important signals directing the insect towards its host plant. In the absence of visual orientation, they are essential for night-active phytophagous insects and, in some cases, seem to control the reproduction of the latter. Economically important crop plants are increasingly endangered by just a few insect species which have suddenly developed into rampant agricultural pests. Understanding the kind of interplay which is responsible for this ecological imbalance is a prerequisite for the development of practical solutions. A worldwide ecological crisis as well as impending climatic change confer a desperate urgency on this matter. As a new science, biosemiotics qualifies for this task as it focuses on sign-mediated communication as a paramount characteristic of life.

Agriculture today has not only experienced the green revolution but is also experiencing some of the most harmful agricultural pests and diseases which are becoming more and more difficult to control with our present pesticides. Among the most voracious pests are the pod borers, *Heliothis armigera* and *H. zea*. These polyphagous, night-active moths are so well adapted to their new agricultural environment that they are present in almost all warm climates throughout the world. Their main plant hosts are some of our most important cash and food crops, such as cotton, maize, sorghum and legumes; however, there are also many different alternative host plants, including tobacco, tomato, and many wild fruits. *H. armigera* has been reported to have infested 181 different host plant species just in India alone (Manjunath *et al.*, 1985). What makes this moth so harmful to agriculture? Multiple factors control its population, as evidenced by years of very low infestation versus years of disastrous infestation of our crops. One *Heliothis* moth can lay up to 3,000 eggs within a few nights; one can estimate under favourable conditions that its population can increase by a factor 1:50 within just one generation, which means within three weeks. As our crop plants are no more ancestral and consequently not protected by natural selection, they are much more vulnerable to attack by their pests.

One factor within the strategy of integrated pest management is breeding for resistance. Thousands of chickpea and pigeonpea genotypes have already been tested for *Heliothis* tolerance in the field. Some of them have good levels of resistance which they maintain under the changing environmental conditions of different agroclimatic zones, whereas others broke down completely. Out of more than 14,000 chickpea germplasm accessions and breeding lines which have been tested over the last 15 years under open field, unsprayed conditions at ICRISAT, only very few have come out with a good level of *Heliothis* resistance and most of these are susceptible to fungal infections (Lateef and Sachan, 1990). A severe drawback to this classical genetic approach of breeding and screening for resistance is the fact that very few quantitative resistance/tolerance markers are available under the open-field conditions that could directly guide the plant breeder. The reasons for this are obvious, since infestation pressure of the pest insect is never homogenous and constant for a certain screening plot and year. The answer as to how and why the moth finds its host plant and why the growing larva stays on it, is unknown as well. We therefore first have to ask which signals are involved in this plant vs insect interaction and which of them are semiochemicals. This can be illustrated by the identification of two kairomonal principles which are involved in chickpea vs *Heliothis* interaction.

Let us first consider the volatile, distance-perceivable signals. Can pheromones, the species-specific sex attractants, or kairomones, the host specific signals, be used for plant protection directly? There was much hope that pheromones would be useful for insect control. It seemed as if one only had to lure the male pest insects into traps baited with the respective pheromone, and the females would be without mating partners. However, out of many techniques only one strategy turned out to be applicable — monitoring insect populations with pheromone-baited traps. Neither the idea of mating disruption by synthetic pheromones — whereby the pheromone permeates the atmosphere so as to prevent communication among the sexes and hence subsequent mating — nor mass trapping of the males —where large numbers of traps are used to reduce population levels—turned out to be generally applicable, except under very limited conditions. However, monitoring has become an extremely useful method for insect control. Whereas before the first insects which appeared in the field gave the signal for insecticide spraying, now insect monitoring allows much more precise plant protection strategy. What about the other possibility, trapping the female moth? Such an approach would be extremely attractive due to the fact that the female produces the next generation and, as mentioned already, has high reproductive capacity. In other words, it will be much more effective to take the females off, mainly at low population density, than the males.

Kairomones are semiochemicals which are harmful to the emitter and beneficial for the recipient. How to design a behavioural assay for kairomones? Contrary to the highly specific pheromones, such olfactory signals are acting in combination with visual, tactile, and/or gustatory ones. In our *Heliothis* larvae assay system the visual and the tactile stimuli are carefully avoided. We use a trident olfactometer with remote gas supply, two tubes serving the control gas streams, and the third coupled with a Teenax® glass tube carrying the volatiles to be tested. Velocity of gas flow and humidity can be kept at constant level. Sixty first instar larvae are used per test, being placed one at a time at the entrance tube from where it is free to migrate towards one of the three air streams (Rembold *et al.*, 1989a). For the adults, a rectangular chamber (60 x 20 x 20 cm) with glass walls on each side and wire-nets on its two opposite ends is used as a flight tunnel. The whole arena is made of metal and can be cleaned after each test. The source of scents is a rubber septum which is either placed downwind in front of one of the wire-nets or is introduced through a hole in the middle of the upper glass plate. Usually one insect is released into the flight tunnel and is observed for half hour periods (Rembold *et al.*, 1991).

Powdered chickpea seed attracts the larvae of *H. armigera* (Saxena and Rembold, 1984). The volatile components were absorbed on Teenax®, separated by capillary gas chromatography and 132 of them structurally identified (Rembold *et al.*, 1989b). Most of the compounds were terpenoids (35%) and alcohols (18%). From the identified compounds, the 16 most prominent were individually tested in the olfactometer assay. Significant positive orientation was evoked by pentan-1-ol and by a mixture of the three terpenes, delta-3-carene, myrcene and alpha-pinene. The highest attraction was obtained using a synthetic kairomone composed of the four compounds in the same proportion as in the chickpea aroma (Rembold *et al.*, 1989a). When tested with *H. armigera* moths in the flight tunnel, under both long distance and short range conditions, the synthetic chickpea kairomone attracted the mated, egg laying moths, better than the pentan-1-ol or the three terpenes only (Rembold *et al.*, 1991). Upwind orientation of the moths was demonstrated near the source by increased turning and by zigzag flights under downwind situations. The fact that very few of the searching females rested on the source and none tried to lay eggs there demonstrates that they are missing an additional cue for their host-finding. Unmated females reacted poorly to the synthetic kairomone and the males were unaffected. This clear oviposition directed behaviour was also achieved in field experiments where almost exclusively females were caught in kairomone baited pheromone funnel traps. This is a remarkable result in view of the fact that many other plant-specific signals were absent and the traps were placed within the natural host plants. The results from this study therefore demonstrate a clear function of the kairomone in terms of host-finding for oviposition. Surprisingly, the signal had no clear function for the unmated moth. Besides their biosemiotic interest, the results from the kairomone baited traps clearly demonstrate that there is a good chance of developing an efficient strategy for control of *H. armigera* before its population builds up by reducing the number of reproductive females through trapping. Many different applications of this strategy are possible. Besides baited traps, the plant breeder can design trap plants which are either another line of the same crop or a completely different plant which attracts for egg-laying without sustaining survival of the insect larvae. Also the well-known method of intercropping different varieties of the same species must now be studied in relation to the aroma composition of each variety.

Whereas the volatile kairomone is a long-distance perceivable signal for the egg-laying *Heliothis* moth, other semiochemicals are obviously used to finally identify the host-plant for oviposition. The chickpea secretes a highly acidic exudate which has a pH near 1.0. This is released through trichomes which are located on the plant's surface, including the pods. The exudate seems to be involved in chickpea resistance against *H. armigera* attack and the concentration of malate, the main organic acid in chickpea exudate, is positively correlated with this resistance (Rembold, 1981). A more detailed analysis reveals that oxalate is another prominent acid in the chickpea exudate which makes up almost one third of the dry matter. The high acidity is obviously due to presence of some glucose-6-phosphate, whereas the minor components, citrate, succinate, malonate, oxalate, and fumarate make up less than five per cent altogether and don't add to the *Heliothis* resistance of the chickpea (Rembold and Weigner, 1990). Both the exudate dry matter and the malate contents of different chickpea genotypes varies by almost 500% and in some cases there is a clear correlation between borer damage and malate contents, if its concentration is in the range of 250–400 mg/ml exudate. The same holds true for the chickpeas with high borer damage, which have malate contents of 100 mg or less per ml of exudate. If chickpea is grown in a greenhouse in Germany under such completely different agroclimatic conditions enormous differences in the dry-matter composition were found, if malate and oxalate were compared. Some interesting differences also become apparent on the basis of substance per leaf surface. During the day, total malate is constant, but oxalate is variable for each cultivar. The same situation was observed during the whole maturation period of each of the cultivars studied (Rembold *et al.*, 1990).

These two examples may demonstrate how chemical signals are used by a pest insect to identify its host-plant for oviposition and how to keep its larvae on it. In order to learn more about the orientation behaviour of a polyphagous insect like *H. armigera*, we also studied the kairomone from one of its alternative hosts, the pigeonpea, *Cajanus cajan*. Interestingly enough, this signal is chemically completely different from the chickpea kairomone; it is composed of sequiterpenes (Rembold and Tober, 1985) instead of terpenes. The reaction to the synthetic pigeonpea kairomone is even stronger than to the chickpea volatiles and it is effective in concentrations which are in the pheromone range. In terms of biosemiotics, this lesson demonstrates to some extent the network of interacting environmental signals which guide a pest insect in its ecosystem. With the help of an unknown programme the insect also "knows" when one of its host plants is no longer relevant to its needs and consequently the insect has to lay eggs on an alternate host plant, which may be another crop plant or a weed. This fact is well known to the farmer who grows lines with different maturation periods and so to some extent escapes from infestation of his crop by some pests. However, there is still a long way to go till we come to a real understanding of the mystery of "how an insect comes to a decision" and how we can make use of this knowledge in a way which is less defensive and much more persuasive than our present plant protection strategies.

ACKNOWLEDGEMENT

Our coworkers are cited in the published literature. The project on chemical basis of host-plant resistance is financially supported by GTZ, Eschborn, Germany.

REFERENCES

Anderson, M., J. Deely, M. Krampen, J. Ransdell, T. A. Sebeok and T. V. Uexkull (1984). A semiotic perspective on the sciences: steps toward a new paradigm. *Semiotica* 52, 7–47.

Eder, J. and H. Rembold (1991) Biosemiotics — a paradigm for the biological sciences. *Naturwissenschaften*, (in press).

Lateef, S. S. and J. N. Sachan (1990). Host-plant resistance to *Helicoverpa armigera* in different agroecological contexts. In *Chickpea in the Nineties: Proc. 2nd Internat. Workshop on Chickpea Improvement*, pp 181–189. 4–8 Dec. 1989, ICRISAT Centre, Patancheru, India (Eds. H. A. van Rheenen and M. C. Saxena). ICRISAT.

Manjunath, T. M., V. S. Bhatnagar , C. S. Pawar and S. Sithanantham (1989) Economic importance of *Heliothis* spp. in India and an assessment of their natural enemies and host plants. In *Proc. Workshop Biol. Control of* Heliothis: *Increasing the Effectiveness of Natural Enemies*, 11–15 Nov. 1985, New Delhi, India, pp 197–228, (Eds. E. G. King and R. D. Jackson), Far Eastern Reg. Res. Office, USDA, New Delhi, India.

Rembold, H. (1981). Malic acid in chickpea exudate — a marker for *Heliothis* resistance. *International Chickpea Newsletter* 4, 18–19.

Rembold, H. (1987) Caste differentiation of the honey bee. In *Chemistry and Biology of Social Insects*, pp 3–13, (Eds. J. Eder and H. Rembold), J. Verlag Peperny, Munchen.

Rembold, H. and J. Eder (1991). Biosemiotics —a paradigm of biology. Signals controlling deterministic chaos. 22nd International Ethological Conference, 22–29 August 1991, Kyoto.

Rembold, H. and H. Tober (1985). Kairomones as pigeonpea resistance factors against *Heliothis armigera*. *Insect Sci. Applic.* 6, 249–252.

Rembold, H. and Ch. Weigner (1990) Chemical composition of chickpea, *Cicer arietinum*, exudate. *Z. Naturforsch.* 45c, 922–923.

Rembold, H., P. Wallner and A. K. Singh (1989a) Attractiveness of volatile chickpea (*Cicer arietinum* L.) seed components to *Heliothis armigera* larvae (Lep., Noctuidae). *J. Appl. Ent.* 107, 65–70.

Rembold, H., P. Wallner, S. Nitz , H. Kollmannsberger and F. Drawert (1989b). Volatile components of chickpea (*Cicer arietinum* L.) seed. *J. Agric. Food Chem.* 37, 659–662.

Rembold, H., A. C. Kohne and A. Schroth (1991). Behavioral response of *Heliothis armigera* Hb. (Lep., Noctuidae) moths on a synthetic chickpea (*Cicer arietinum* L.) kairomone. *J. Appl. Ent.* 109, (in press).

Rembold, H., P. Wallner, A. Kohne , S. S. Lateef, M. Grune and Ch. Weigner (1991). Mechanisms of host-plant resistance with special emphasis on biochemical factors. In *Chickpea in the Nineties: Proc. 2nd Internat. Workshop on Chickpea Improvement*, pp 191–194, 4–8 Dec. 1989, ICRISAT Centre, Patancheru, India (Eds. H. A. van Rheenen and M. C. Saxena), ICRISAT.

Sebeok, T. A. (1972). *Perspectives in Zoosemiotics*. Mouton Publishers, The Hague.

Wenner, A. M. (1968). Honey bees. In *Animal Communication*, pp 217–243, (Ed. T. A. Sebeok), Indiana University Press, Bloomington, USA.

Effective and Sustainable Ecotechnology Development with a Specific Example of Tsetse Control

R. K. Saini and A. Hassanali

Behavioural and Chemical Ecology Research Unit,
The International Centre of Insect Physiology and Ecology
(ICIPE), P. O. Box 30772, Nairobi, Kenya

SUMMARY

In this overview, we examine how detailed knowledge of chemical ecology and behavioural ecology of the pest or disease vector can provide a technical basis of developing novel pest management strategies. Three examples of ecotechnology (redefined as the application of behavioural and chemical ecology in the development of pest or vector management) development are illustrated. The first addresses the question of relatively slow progress achieved to-date in the application of pheromones and other semiochemicals and points out the need for a better understanding of different biotic and abiotic factors that may affect semiochemical mediated communication. The second highlights the unfolding patterns of multitrophic interactions and the opportunities that the understanding of these augur for the development of biocontrol approaches. (Two signals with hitherto undescribed roles in interspecific interactions, termed "kairochemic" and "allochemic", are also described). The third focuses on a success story in the control of the tsetse *Glossina pallidipes* based on the development of an appropriate ecotechnology resulting from multi-disciplinary research embracing population ecology, behaviour, chemical and visual cues as well as on a high profile participation of the client community.

INTRODUCTION

Current concepts in the control of arthropod pests and disease vectors are dominated by the desire and need for approaches that minimise any negative impact on the biosphere, that do not lead to rapid development of resistance in the target arthropods, and that place minimum reliance on environmentally persistent synthetic pesticides. Such ecologically rational approaches to pest management demand a thorough knowledge of the biology of the pest species and the complex inter-relationships and co-adaptations that exist between them and other members of the ecosystem in which the pest occurs. In recent years, several closely related and overlapping areas of study have been concerned with understanding the bases of varied inter- and intra-specific interactions of pest species, and in elucidating how these affect their natural patterns and life styles and those of the organisms they interact with. These areas include ethological and behavioural research, bio-control research and the emerging science of chemical ecology. In this paper, we illustrate how detailed knowledge in these areas can provide opportunities in the development of novel and imaginative pest management strategies.

Effective exploitation of these areas demands a holistic view of the ecosystem harbouring the target pest whose survival depends not only on its ability to locate its mate and food source, but also to avoid its enemies and noxious food, adapt to new situations and, if need be, emigrate. The pest's competitiveness in the ecosystem and the successful performance of its varied tasks depend upon its communication system which links it, on the one hand, to conspecifics, host and non-host plants or animals, and, on the other, to its enemies such as parasitoids, predators and microbial agents. Of importance is the recognition that the pest's communication system is predicated on a multiplicity of cues, both chemical and biophysical, and is modified by the behaviour or the physiological state of members of different trophic levels as well as by other biotic and abiotic factors in the environment.

Murray Blum (1985) proposed the use of the term "eco-technology" for the application of the growing number of natural chemical agents spawned by chemical ecology. Applications being explored involve both, non-chimeric use of behaviour-controlling or physiology-modifying chemical agents and chimeric use of such agents integrating a combination of disparate bioregulators such as semiochemicals with insecticides, pathogens, predators or parasitoids. A dominant and critical component of many of these approaches to insect pest control comprises behavioural manipulation of the pest or the control agent, often involving the use of several cues both chemical and non-chemical. Elsewhere, it has been argued that a comprehensive behavioural ecology perspective would benefit aspects of pest management, including the use of semiochemicals (Roitberg and Augerilli, 1986; McNeil, 1991). Accordingly, we propose a broadening of the conceptual scope of "eco-technology" to comprise the application of behavioural and chemical ecology in achimeric or chimeric approaches to the development of pest and vector management.

Three examples in eco-technology development are illustrated here:

1. The knowledge base needed for an effective use of pheromones and other semiochemicals in integrated pest management.

2. The unfolding patterns of multitrophic interactions and the implications of these in pest management.

3. A specific case of the development of a population suppression system for the tsetse *Glossina pallidipes* and its successful management by the client community.

The last example is designed to underpin important prerequisites in the successful adoption of any eco-technology: a sustainable strategy for its management and a demonstrable beneficial socio-economical impact for the target community.

TOWARDS MORE EFFECTIVE USES OF PHEROMONES

Insects primarily depend on chemical stimuli for successfully carrying out essential activities in their life cycles and hence manipulation of these stimuli presents a tempting opportunity to modify insect behaviour and, thus to regulate reproduction and survival. Not surprisingly, some of the pioneering efforts in the development of ecotechnologies that have been employed in rational management programmes have involved the use of semiochemicals, and, in particular, pheromones. The use of pheromones in the regulation of insect populations has been reviewed on several occasions (see Birch, 1974; Shorey and McKelvey, 1977; Ritter, 1979; Roelofs, 1979; Mitchell, 1981; Nordlund *et al.*, 1981; Silverstein, 1981; Kydonieus and Beroza, 1982; Leonhardt and Beroza, 1982; Campion, 1985; Jutsum and Gordon, 1989; Mayer and Mclaughlin, 1990; McNeil, 1991).

Although the pheromones of many major pest species have been identified and synthesised, progress towards widespread practical use of these chemicals has been slower than expected. Significantly, data on practical applications of pheromones in monitoring, mass trapping or mating disruption have been published for less than 5% of species for which pheromones have been identified (Jutsum and Gordon, 1989). This slow progress has been mainly due to lack of prior thorough understanding of the biology of the insect. In any case, our expectations were probably too high given inadequate databases (McNeil, 1991). This observation does not question the obvious potential of semiochemicals, but rather underlines the need to increase our understanding of the factors that influence their efficacy. Tumlinson (1988) highlights five areas where additional research may improve our use of semiochemicals: identification of optimum blends which are as good as natural blends, development of appropriate formulations for their release, a better understanding of the mechanisms and of biosynthetic pathways of pheromone synthesis, increase in the knowledge of the mechanisms of semiochemical reception and increased research on other semiochemicals of potential use in pest management. The new potentially useful groups of semiochemicals include epideictic pheromones (Prokopy, 1981), kairomones that influence the behaviour of natural enemies (Vinson, 1977) and host plant volatiles that influence oviposition (Renwick, 1989).

The most serious bottleneck in optimal use of pheromones may be the lack of information on behavioural ecology relating to semiochemical mediated communication (Sanders, 1989). McNeil (1991) has reviewed the different biotic and abiotic factors that may influence emission and reception of pheromones, and has discussed how a better understanding of these behavioural and ecological components may also help in the intepretation of trap-catch data and permit more efficacious use of pheromones. Some of the biotic factors that need further investigation are: effect of age on pheromone compositions and emissions and relative attractiveness of different aged females during the calling period; effect of changing ages and different emission rates; effect of female calling on conspecifics and others of the same sex. Does a male attracted to the pheromone inhibit attraction behaviour of other conspecific males? Is the result of broadcast pheromone application in mating disruption solely a function of a modification in the males' behaviour? If the females also respond to the pheromone in a way as to lead to enhanced mating disruption, can this effect be optimised through chemical formulation or application changes? How does previous mating experience affect male responsiveness to different blends and concentrations of sex pheromones? What is the effect of host plants on female calling and male receptivity? What is the effect of sublethal pathogenic infections on the synthesis and emission of female pheromones as well as on male receptivity?

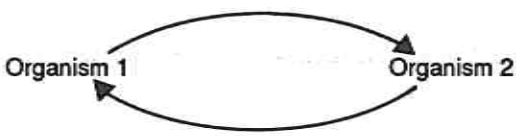
Among the abiotic factors, the effects of temperature, day length, light intensity, relative humidity and wind speed on female calling behaviour and male receptivity need to be studied in more detail. Better knowledge of all these factors will not only lead to the development of appropriate formulations and dispensers, but a better understanding of trap catches and more effective manipulation of insect behaviour.

Finally, as with any management tool, the operational use of pheromones must be considered in the context of an integrated pest management system as well as the social and economic milieu which may influence their adoption.

MULTITROPHIC INTERACTIONS AND THEIR IMPLICATION FOR PEST MANAGEMENT

Recent research on trophic relationships within insect communities have begun to reveal the existence of a wide network of interspecific semiochemical signals that link different trophic levels (Price *et al.*, 1980; Whitman, 1988). Between any two levels, six theoretical categories of interactions are possible depending upon benefit or harm associated with the signal emitted by a member of interacting pair (Fig. 1). Thus in any multitrophic network, a large

Fig. 1. **Possible allelochemical interactions between two trophic levels: the arrow links the emitter to the receiver and the signal emitted may play one of the six possible roles indicated; a '+' indicates benefit, a '–' indicates harm and a '±' indicates a neutral role of the signal. (Each of the first four signals may be beneficial, harmful or neutral with respect to other organisms in a multitrophic system).**
***These terms are proposed for signals emitted by an organism that affect the relationship between members of the first two trophic levels.**



	Benefit/Harm		
	Emitter	Receiver	3rd Organism
Allomone	+	-	
Kairomone	-	+	
Synomone	+	+	
Antimone	-	-	
Kairochemic*	±	+	-
Allochemic*	±	-	+

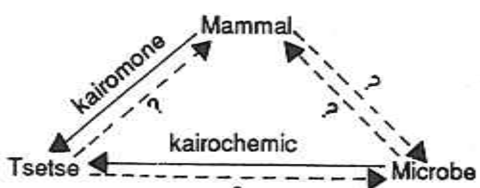
number of theoretical combinations of allelochemical relationships are possible. Tritrophic relationships have been subject of special attention because of the new light they have thrown on the mechanisms of host location by pests, predators and parasitoids and, particularly, because of the implication of these in pest management. Some examples of these are presented below.

(a) Microbial Facilitation of Host-Finding by Tsetse

As pointed out elsewhere in this paper, phenols play an important mediating role in host location by certain species of tsetse (Hassanali *et al.*, 1986; Owaga *et al.*, 1988; Vale *et al.*, 1986). These attractants have been shown to form gradually through microbial activity from pro-attractants identified as a mixture of glucuronates and sulphates present in urine and sweat of the host (Okech and Hassanali, 1990). One of the bacteria was identified as *Aerococcus viridans*.

Thus, host location by tsetse is facilitated by two sets of attractants: those produced by the host mammal (kairomones) and those produced as a result of microbial activity (for which we propose the term "kairochemic" to distinguish it from "kairomone" because the emitting organism itself is unaffected, although it facilitates an interaction between organisms in the first and second trophic levels benefitting the latter at the expense of the former; likewise, we propose the term "allochemic" for a signal which affects the receiving organism deleteriously to the advantage of the organism in the first trophic level). The relationship between this tritrophic system is illustrated in Fig. 2. Concurrent use of the two types of attractants has been the basis of a very successful bait technology for the suppression of *Glossina pallidipes* described later in this paper.

Fig. 2. Allelochemical interactions between tsetse, mammalian host and microbes

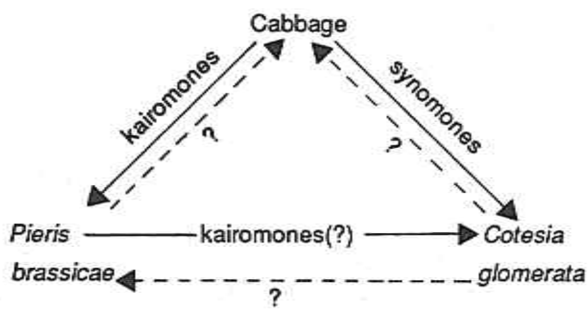


(b) Synomonal Facilitation of Host-Finding by Parasitoids

Useful insights have recently come from studies involving plant-herbivore-parasitoid interactions. The strategies employed by natural enemies of herbivorous insects to locate their victims have been of special interest (Nordlund *et al.*, 1981; Vinson, 1976, 1981; Weseloh, 1981). One such strategy involves the use of intraspecific communicational signals (pheromones) as kairomones for the location of the insect from a distance (e.g. Vite and Williamson, 1970; Lewis *et al.*, 1982; Noldus *et al.*, 1991), although emanations other than pheromones have also been used (Ulyett, 1953; Monteith, 1964; Nettles, 1980). It has been argued that herbivore-derived signals, although very reliable, are not easy to detect by organisms in the third trophic level (Vet and Dicke, 1992; Wackers and Lewis, 1992). A second strategy may be based on plant derived signals. Although, these are well dẽtectable, they are unreliable in indicating the presence of herbivores and their identity (Steinberg *et al.*, 1993). Thus, it has been hypothesised that herbivore enemies are faced with a reliability-detectability dilemma (Vet and Dick, 1992; Wackers and Lewis, 1992). One way this problem has been solved is by the use of specific plant-derived signals induced by plant-herbivore interactions (Greany and Hagen, 1981; Flint *et al.*, 1979; Steinberg *et al.*, 1993). The larval parasitoid *Cotesia glomerata* is one such organism in the third trophic level that relies on herbivore-induced synomones from the host plant (cabbage) in long-range host (*Pieris brassicae*) location (Steinberg *et al.*, 1992) (Fig. 3). Likewise, the female *Epidinocarsis lopezi*, a parasitoid of the cassava mealybug, limit their search for hosts to infected plants (Nadel and van Alphen, 1987), relying on specific volatiles produced by the cassava plant in response to mealybug attack.

Identification of the synomones involved in such tritrophic interactions and elucidation of the mechanisms of their release are likely to open up exciting ways of optimising the use of parasitoids in the control of herbivorous pests.

Fig. 3. Allelochemical interactions between cabbage, one of its pests and a parasitoid



TSETSE, *GLOSSINA PALLIDIPES* COMMUNITY-BASED SUPPRESSION SYSTEM

Over the years, the main goal of ICIPE's tsetse research has been to develop new efficacious strategies for reducing trypanosomiasis challenge to animals and humans through vector control. Such strategies would not only be environmentally friendly but also sustainable and suitable for use by resource poor rural communities. In addition, it would be advantageous if the new technology would be low cost, make use of locally available materials, be less dependent on insecticides and encourage sustainable and ecologically desirable land use practices in the areas in which it is to be applied.

ICIPE's approach to tsetse control has been based on four vital ingredients (Odhiambo, 1990):

(i) A knowledge rich control strategy, which attempts to have a comprehensive understanding of individual tsetse species and their holistic world — as it sees and communicates with its own tsetse community, as it interacts with and gathers intelligence on its animal and human hosts, and as it employs its biological potential to manange its life in an often hostile environment.

(ii) A high-profile community approach, since the militaristic aerial spraying operations are unviable, unsustainable and have deleterious effects on the ecosystem.

(iii) Sustainability on a long term basis.

(iv) The development of a suitable tsetse trap as the basic foundation of a community-oriented integrated pest management package for tsetse and trypanosomiasis.

Studies on the population dynamics of *G. pallidipes* (Dransfield *et al.*, 1989 a,b; Williams *et al.*, 1990) indicated that if an additional mortality of about 3% could be sustained, an isolated tsetse population will be eradicated within one year. Accordingly, one of the key objectives was the development of a trapping system that would be simple to construct, easy to maintain and at the same time be cost effective for some of the poorest communities in Africa. Starting from the Challier - Laveissiere bioconical trap, which had proved its high visual attractancy in West Africa (Challier *et al.*, 1973), the work resulted in the development of several trap designs of which the NG2B was found to be the most effective for *G. pallidipes* and *G. longipennis* (Brightwell *et al.*, 1987, 1991). This trap is made of blue and black cloth with an upper cone of white muslin netting (Brightwell *et al.*, 1987). The blue cloth of the trap attracts the flies and the black cloth elicits a landing response. Flies enter the trap from below and are then attracted upwards towards the light filtering through the muslin cone, where they are trapped in a plastic bag and die from heat stress. No insecticide is used. This method of trapping and killing flies is thus very specific and environmentally non-polluting. The NG2B traps were later modified to include a "wing" of an additional metre of blue cloth on one side of the trap and a new cage design (NG2G) (Brightwell *et al.*, 1991).

Parallel to research in trap development, attention was also being devoted to host selection behaviour of tsetse and in particular to the chemical cues involved in finding a host animal and those that eventually lead to landing and engorgement. Taking a clue from Chorley's work (1948) that *G. pallidipes* congregates at buffalo resting places and *G. morsitans* at elephant resting places where dung and urine accumulate, Owaga (1984, 1985) demonstrated that buffalo urine was a potent attractant for *G. pallidipes*. This discovery was followed by carefully designed behavioural, electrophysiological, chemical analytical work and field ecological work which established the chemical identity and characteristics of the compounds (4-cresol and 3-n-propylphenol) primarily responsible for attractancy (Saini, 1986; Hassanali *et al.*, 1986; Saini *et al.*, 1987; Owaga *et al.*, 1988; Saini, 1990; Saini and Hassanali, 1992). Moreover, Okech and Hassanali (1990) showed that phenolic tsetse attractants were formed as a result of breakdown of precursors in the urine by specific microbial activity and this resulted in a natural slow release of the attractive phenols.

In Zimbabwe, another group, working independently, identified carbon dioxide, acetone, 1-octen-3-ol and butanone (Vale, 1980; Hall *et al.*, 1984; Bursell, 1984; Vale and Hall, 1985 a,b; Vale *et al.*, 1986) as the attractive kairomones in ox breath. Saini *et al.* (1989) also undertook structure activity work on 1-octen-3-ol analogues and identified 1-octyn-3-ol, 3-buten-2-ol, allyl alcohol and 1-octen-3-one as attractive compounds.

All this information laid the basis for a pilot control operation at Nguruman, in the Rift Valley in Kenya (Dransfield *et al.*, 1990; Brightwell *et al.*, 1991; Dransfield *et al.*, 1991). The NGU traps used in the control operation were all made by the community (Maasai) in their homesteads (Manyattas). The local community through their group ranch management committee undertook to protect the traps and also to assist in their servicing. 200 traps baited with acetone and fermented cow urine were deployed over 120 km² of the ranch. Within eight months, catches in the suppression zone had fallen by about 99% relative to catches outside the suppression zone. In fact, ever since and in spite of repeated seasonal invasions, the fly density has been maintained below 10% and at times as low as 0.1% of the fly density outside the suppression zone.

The impact of this simple community-based, pollution-free ecotechnology on the incidence of trypanosomiasis has been remarkable (Dransfield *et al.*, 1991). In addition, new grazing and browsing land has been made available. Dransfield *et al.* (1991) estimate that one NGU trap with odour baits costs US$15 per year to make and operate, excluding labour and transport costs for servicing. According to these authors in an area like Nguruman, 2–3 traps per km² are enough to sustain a 90–99.9% reduction in *G. pallidipes*. Even if the community's labour and transport costs are added, the overall cost of the technology is well below that of other government administered techniques such as ground spraying (US$110/km²/year), insecticide impregnated targets (US$ 170/km²/year) and aerial spraying (US$240/km²/year) (Vale *et al.*, 1988). Thus, the success of the Nguruman operation demonstrates exciting prospects for similar approaches to pest and vector management.

Recently, Saini *et al.* (1993) have shown that additional kairomones are present on the bodies of host animals which at close range induce arrestment, alighting and probing behaviour. The results of these studies confirmed earlier speculation that host seeking behaviour of tsetse flies is quite complex and that it may be important to distinguish between initial distant orientation to host animals and localised orientation at close range which eventually leads to successful engorgement. A combination of attractants associated with these responses may be responsible for the host selectivity of different species of tsetse. A thorough understanding of such behavioural patterns relating to different species and populations and their semiochemical basis is one of the keys to efficient management of these insects.

REFERENCES

Birch, M. C. (Ed.) (1974). Pheromones, North-Holland Research Monographs, *Frontiers of Biology* 32, 495.

Blum, M. S. (1985). Chemical ecology and pest control roles of ecotechnology and chimeric bioregulators. *Proc. XVIII Pesticide Science Symposium and*

Public Lectures, Oct. 1985. (Toyama, Tokyo, Kobe).

Brightwell, R., R. D. Dransfield, C. Kyorku, T. K. Golder, S. A. R. Tarimo and D. Mungai (1987). A new tsetse trap for *Glossina pallidipes*. *Trop. Pest Manage*. 33, 151–159.

Brightwell, R., R. D. Dransfield, and C. Kyorku (1991). Development of a low-cost tsetse trap and odour baits for *Glossina pallidipes* and *G. longipennis* in Kenya. *Med. Vet. Entomol.* 5, 153–164.

Campion, D. G. (1985). Survey of pheromone uses in pest control. In *Techniques in Pheromone Research*, pp 405–449, (Eds. H.E. Hummel and T. A. Miller), Springer-Verlag, New York.

Challier, A., M. Eyraud, A. Lafaye and C. Laveissiere (1973). Amelioration du rendement due piege biconique pour glossines (Diptera, Glossinidae) par l'emploi du'un cone inferieur bleu. *Cah. ORSTOM Ser., Med. Entomol. Parasitol.* 11, 251–262.

Chorley, T. W. (1948). *Glossina pallidipes* Austen attracted by the scent of cattle dung and urine (Diptera). *Proc. Entomol. Soc.* London A. 23, 9–11.

Dransfield, R. D., R. Brightwell, J. Kilu, M. F. B. Chaudhury, and D. A. Adabie (1989a). Size and mortality rates of *Glossina pallidipes* in the semi-arid zone of south western Kenya. *Med. and Vet. Ent.* 3, 83–95.

Dransfield, R. D. and R. Brightwell (1989b). Problems of field testing theoretical models. A case study. *Ann. Soc. Belge. Med. Trop. Suppl.* 1, 149–154.

Dransfield, R. D., R. Brightwell, C. Kyorku and B. Williams (1990). Control of tsetse fly (Diptera: Glossinidae) populations using traps at Nguruman, South-West Kenya. *Bull. Entomol. Res.* 80, 265–276.

Dransfield, R. D., B. G. Williams, and R. Brightwell (1991). Control of tsetse flies and trypanosomiasis: Myth or Reality? *Parasitology* 7, 10 (76)287–291.

Flint, H. M., S. S. Salter and S. Waters (1979). Caryophyllene: an attractant for the green lacewing *Crysopa carnea* Staphous. *Environ. Ent.* 8, 1123–1125.

Greany, P. D. and K. S. Hagen (1981). Prey selection. In *Semiochemicals: Their*

Role in Pest Control, pp 121–175, (Eds. D. A. Nordlund, R. L. Jones and W. J. Lewis), Wiley, New York .

Hall, D. R., P. S. Beevor, A. Cork, B. F. Nesbitt and G. A. Vale (1984). 1-octen 3-ol: a potent olfactory stimulant and attractant for tsetse isolated from cattle odours. *Insect Sci. Applic.* 5, 335–339.

Hassanali, A., P. G. McDowell, M. L. A. Owaga and R. K. Saini (1986). Identification of tsetse attractants from excretory products of a wild host animal, *Syncerus caffer*. *Insect Sci. Applic.* 7, 5–9.

Jutsum, A. R. and R. F. S. Gordon (Eds.) (1989). *Insect Pheromones in Plant Protection.* John Wiley & Sons Ltd.

Kydonieus, A. F. and M. Beroza, (Eds.) (1982). *Insect Suppression with Controlled Release Pheromone Systems*. CRC Press, Boca Raton, Florida, USA (2 vols).

Leonhardt, B. A. and M. Beroza, (Eds.) (1982). Insect pheromone technology: chemistry and application. ACS *Symposium Series* 190, American Chemical Society, Washington, DC, 299 pp.

Lewis, W. J., D. A. Nordlund, R. C. Gueldner, P. E. A. Teal and J. H. Tumlinson (1982). Kairomones and their use for management of entomophagous insects. XIII. Kairomonal activity for *Trichogramma* spp. of abdominal tips, excretion and synthetic sex pheromone blend of *Heliothis zea* (Boddie) moths. *J. Chem. Ecol.* 8, 1323–1331.

Mayer, M. S. and J. R. Mclaughlin (Eds.) (1990). *CRC Handbook of Insect Pheromones and Sex Attractants.* CRC Press, Boca Raton, Florida, USA.

McNeil, J. N. (1991). Behavioural ecology of pheromone-mediated communication in moths and its importance in the use of pheromone traps. *Annu. Rev. Entomol.* 36, 407–430.

Mitchell, E. R. (Ed.) (1981). *Management of Insect Pests with Semiochemicals: Concepts and Practice.* Plenum Press, New York, 514 pp.

Monteith, L. G. (1964). Influence of the health of food plant of the host on host finding by tachnid parasities. *Can. Entomol.* 96, 1477–1482.

Nadel, H. and J. J. M. van Alphen (1987). The role of host and host plant odours in the attraction of a parasitoid, *Epidinocarsis lopezi*, to the habitat of its host, the cassava mealybug, *Phenacoccus manihoti*. *Entomol. exp. appl.* 45, 181–186.

Nettles, W. C. (1980). Adult *Eucelatoria* sp: Response to volatiles from cotton and okra plants and from larva of *Heliothis virescens*, *Spodoptera eridnia* and *Estigmene acrea*. *Environ. Entomol.* 10, 177–187.

Noldus, L. P. J., J. C. van Lenteren and W. J. Lewis (1991). How Trichogramma parasitoids use moth sex pheromones as kairomone: orientation behaviour in a wind tunnel. *Physiol. Entomol.* 16, 313–327.

Nordlund, D. A., R. L. Jones and W. J. Lewis (1981). *Semiochemicals, Their Role in Pest Control.* Wiley & Sons, New York, 306 pp.

Odhiambo, T. R. (1990). Keynote address. *Insect Sci. Applic.* 11, 259–263.

Okech, M. and A. Hassanali (1990). The origin of phenolic tsetse attractants from host urine: studies on the proattractants and microbes involved. *Insect Sci. Applic.* 11, 363–368.

Owaga, M. L. A. (1984). Preliminary observations on the efficacy of olfactory attractants derived from wild hosts of tsetse. *Insect Sci. Applic.* 5, 87–90.

Owaga, M. L. A. (1985). Observations on the efficacy of buffalo urine as a potent olfactory attractant for *Glossina pallidipes* Austen. *Insect Sci. Applic.* 6, 561–566.

Owaga, M. L. A., A. Hassanali and P. G. McDowell (1988). The role of 4-cresol and 3-n-propylphenol in the attraction of tsetse flies to buffalo urine. *Insect Sci. Applic.* 9, 95–100.

Price, P. W., E. C. Bouton, B. A. Gron, J. N. McPharm and A. N. Weis (1980). Interactions among three trophic levels: influence of plants in interactions between insect herbivore and natural enemies. *Ann. Rev. Ecol.* 11, 41–65.

Prokopy, R. J. (1981). Epideictic pheromones that influence spacing patterns of phytophagous insects. In *Semiochemicals: Their Role in Pest Control*, pp 181–213, (Eds. D. A. Nordlund, R. L. Jones and W. J. Lewis), Wiley, New York.

Renwick, J. A. (1989). Chemical ecology of oviposition in phytophagous insects. *Experientia* 45 , 223–228.

Ritter, F. J. (Ed.) (1979). *Chemical Ecology: Odour Communication in Animals.* Elsevier North-Holland Biomedicals Preps, Amsterdam, 427 pp.

Roelofs, W. L. (Ed.) (1979). Establishing efficacy of sex attractants and disruptants for insect control. *Entomol. Soc. Am.* 97 pp.

Roitberg, B. D. and N. P. D. Angerilli (1986). Management of temperate-zone deciduous fruit pests: Applied behavioural ecology. In *Agricultural Zoology Reviews*, pp 137–165, (Ed. G. E. Russel), Newcastle upon Tyne: Intercept.

Saini, R. K. (1986). Antennal responses of *Glossina morsitans morsitans* to buffalo urine — a potent olfactory attractant of tsetse flies. *Insect Sci. Applic.* 7, 771–775.

Saini, R. K. and R. D. Dransfield (1987). A behavioural bioassay to identify attractive odours for Glossinidae. *Med. Vet. Entomol.* 1, 313–318.

Saini, R. K., A. Hassanali and R. D. Dransfield (1989). Antennal responses of tsetse to analogues of the attractant 1-octen-3-ol. *Physiol. Entomol.* 14, 85–90.

Saini, R. K. (1990). Responses of tsetse, *Glossina* spp (Diptera: Glossinidae) to phenolic kairomones in a wind tunnel. *Insect Sci. Applic.* 11, 369–375.

Saini, R. K. and A. Hassanali (1992). Olfactory sensitivity of tsetse to phenolic kairomones. *Insect Sci. Applic.* 13, 95–101.

Saini, R. K., A. Hassanali, P. Ahuya, J. Andoke and E. Nyandat (1993). Close range responses of tsetse flies *Glossina morsitans morsitans* Westwood (Diptera: Glossinidae) to host body kairomones. *Discovery and Innovation* 5, 149–153.

Sanders, C. J. (1989) . The further understanding of pheromones: Biological and chemical research for the future. In *Insect Pheromones in Plant Protection*, pp 323–351, (Eds. A. R. Jutsum and R. F. S. Gordon), John Wiley & Sons Ltd.

Shorey, H. H. and J. J. McKelvey, Jr. (Eds.) (1977). *Chemical Control of Insect Behaviour: Theory and Application.* Wiley, London, 414 pp.

Silverstein, R. M. (1981). Pheromones: Background and potential for use in insect pest control. *Science* 213, 1326–1332.

Steinberg, S., M. Dicke, L. E. M. Vet and R. Wanningen (1992). Response of the brachonid parasitoid *Cotesia* (= *Apanteles*) *glomerata* to volatile infochemicals: Effect of bioassay set up, parasitoid age and experience and barometric flux. *Entomol. Exp. Appl.* 63, 163–175.

Steinberg, S., M. Dicke, and L. E. M. Vet (1993). Relative importance of infochemicals from first and second trophic level in long-range host location by the larvae parasitoid *Cotesia glomerata*. *J. Chem Ecol.* 19, 47–59.

Tumlinson, J. H. (1988). Contemporary frontiers in insect semiochemical research. *J. Chem. Ecol.* 14, 2109–2130.

Ullyet, G. C. (1953). Biomathematics and insect population problems. *Entomol. Soc. South Afr. Mem.* 2, 1–89.

Vale, G. A. (1980). Field studies of the responses of tsetse flies (Glossinidae) and other Diptera to carbon dioxide, acetone and other chemicals. *Bull. Entomol. Res.* 70, 563–570.

Vale, G. A. and D. R. Hall (1985a). The role of 1-octen-3-ol, acetone and carbon dioxide in the attraction of tsetse flies, *Glossina* spp (Diptera: Glossinidae) to ox odour. *Bull. Entomol. Res.* 75, 209–217.

Vale, G. A. and D. R. Hall (1985b). The use of 1-octen-3-ol, acetone and carbon dioxide to improve baits for tsetse flies, *Glossina* spp. (Diptera: Glossinidae) *Bull. Entomol. Res.* 75, 219–231.

Vale, G. A. Flint, S. and D. R. Hall (1986). The field responses of tsetse flies, *Glossina* spp (Diptera: Glossinidae), to odours of host residues. *Bull. Entomol. Res*. 76, 685–693.

Vale, G. A., D. F. Lovemore, J. Flint, and G. F. Cockbill (1988). Odour baited targets to control tsetse flies, *Glossina* spp (Diptera, Glossinidae) in Zimbabwe. *Bull. Ent. Res.* 78, 31–49.

Vale, G. A., D. R. Hall and A. J. E. Gough (1988). The olfactory responses of tsetse flies *Glossina* spp (Diptera: Glossinidae) to phenols and urine in the field. *Bull. Ent. Res.* 78, 293–300.

Vet, L. E. M., and M. Dicke (1992). Ecology of infochemical use by natural enemies of herbivores in a tritrophic context. *Annu. Rev. Entomol.* 37, 141–172.

Vite, J. and D. L. Williamson (1970). *Thanasimus dubius* prey perception. *J. Insect Physiol.* 16, 233–239.

Vinson, S. B. (1976). Host selection by insect parasitoids. *Annu. Rev. Entomol.* 21, 109–134.

Vinson, S. B. (1977). Behavioural chemicals in the augmentation of natural enemies. In *Biological Control Augmentation by Natural Enemies*, pp 237–279, (Eds. R. L. Ridgway and S. B. Vinson), New York: Plenum.

Vinson, S. B. (1981). Habitat location. In *Semiochemicals: Their Role in Pest Control*, pp 51–77, (Eds. D. A. Nordlund, R. L. Jones, and W. J. Lewis), Wiley, New York.

Wackers, F. L., and W. J. Lewis (1992). Olfactory and visual learning and their interaction in host site location by *Microplitis croceipes*. *Biol. Control* (in press).

Weseloh, R. M. (1981). Host location by parasitoids. In *Semiochemicals: Their Role in Pest Control*, pp 79–95, (Eds. D. A. Nordlund, R . L. Jones, and W. J. Lewis), Wiley, New York.

Williams, B. G., R. D. Dransfield and R. Brightwell (1990). Tsetse fly population dynamics and the estimation of mortality rates from life-table data. *Bull. Entomol. Res.* 80, 479–485.

Whitman, D. W. (1988). Allelochemical interactions among plants, herbivores and their predators. In *Novel Aspects of Insect-Plant Interactions*, pp 11–64, (Eds. P. Barbara and D. Letourneau), Wiley, New York.

Considerations for Success of Community-Based Tsetse Control

L. H. Otieno and A. Oendo

International Centre of Insect Physiology and Ecology, (ICIPE)
P. O. Box 30772, Nairobi, Kenya

SUMMARY

African trypanosomiases are parasitic diseases affecting man and animals and are transmitted by tsetse. Past control methods of these diseases have included moving people out of the tsetse infested areas, bush clearing, game elimination and chemical insecticides spraying campaigns of the affected areas. These techniques have so far not brought any significant changes in the tsetse distribution. What is needed is an efficient, low cost and sustainable control approach involving the full participation of the affected community. In order to ensure success of such control strategy, some considerations of a socio-economic nature must be taken into account.

INTRODUCTION

Sub-Saharan Africa is one of the least developed world regions — comprising most of the world's poorest countries (World Bank, 1990). Agriculture as the mainstay of the economies has hardly kept pace with population growth. The performance of livestock as part of agriculture has not contributed much to the overall development of this industry. Major livestock areas like the Sahel and part of East Africa provide an extremely fragile environment in which the constant threat of drought affects not only the survival of livestock but that of the human population. Animal trypanosomiases has further complicated this very bad situation. Trypanosomiasis is probably the only disease which has profoundly affected the settlement and economic development of the entire sub-Saharan Africa. The magnitude of the problem is such that trypanosomiasis control is an obligatory and high priority undertaking for increasing agricultural production in support of general economic development in Africa.

African trypanosomes are parasitic diseases affecting both humans and animals and are transmitted by tsetse (*Glossina* spp). These diseases are prevalent in Africa between latitudes 15°N and 21°S representing a surface area of approximately 10 million km². The incidence and severity of the disease are dependent upon local conditions and, in consequence, lead to areas where livestock development cannot be raised, or areas where trypanosomiasis-susceptible livestock can be raised using curative and prophylactic trypanocides although tsetse may be present. Animal trypanosomiasis also affects indirectly human health through deprivation of meat and milk products, agricultural production through lack of draught animals and manure and the national economy since the deficit in animal production encourages importation of meat and dairy products.

With present knowledge it is impossible to assess approximate losses caused by animal trypanosomiasis. However, some indication of the magnitude of the problem may be gained by an estimation of the theoretical potential for meat production should the disease be controlled.

Tsetse infested zone potentially exploitable for livestock	7m km²
Average potential carrying capacity	20 cattle/km²
Population of tsetse infested zone	20m cattle
Possibility of increasing cattle population in infested areas	120m herd
Additional meat production	1.5m tons/year
Average cattle productivity in Africa	12.5 kg/head/year
Value of additional meat production (150 cents/kg)	US $ 750m

Source: FAO, 1979

This is an approximate and theoretical estimation since it does not take into account loss of productivity in other sectors of the economy. Nevertheless the message is clear. The potential benefits from trypanosomiasis control thus appears to be considerable.

TSETSE CONTROL

Human Settlement

The oldest method of dealing with the tsetse has been to avoid contact with the fly by moving the human population out of the affected areas. Considering the scope of current tsetse infestation across fertile areas of the African continent and the dire need to develop new sustainable food sources for its expanding human population, de-settlement is not a viable solution to the tsetse problem. Instead it presents tragically missed opportunities for badly needed agricultural development.

Without the tsetse there would be no African trypanosomiasis problem. The dynamic nature of animal trypanosomiasis is primarily determined by movements and changing densities of tsetse populations. The causes of advances and recessions of the tsetse belts are not fully understood. However, Jordan (1988) considers that man, through effects on tsetse habitats and hosts, has had a major impact in the past and, as human numbers increase is having an increasingly profound impact today. In some localities this has the effect of eliminating or reducing tsetse infestation. He considers that in densely populated parts of Africa, such as Nigeria, it is not difficult to foresee the disappearance of the *fusca* and *morsitans* groups of tsetse except in game reserves where their habitats and hosts are protected. The more adaptable species such as *palpalis* group in the humid zones of West Africa and G. *pallidipes* in the savannah of East Africa will, however, persist for the foreseeable future.

Bush Clearing and Game Elimination

During the late 1950s the technique of bush-clearing became popular. This was combined with shooting out the wild herbivorous game, because they were recognised as reservoirs of the disease. Severe erosion and decimation of Africa's already threatened wildlife resulted from this misguided strategy. Such methods are now recognised as inhuman as well as environmentally and ecologically unsuitable.

Use of Chemical Insecticides

In the 1950s chemical insecticides started to be used for insect control. Since the tsetse was and continues to be very sensitive to insecticides, it was generally believed that African trypanosomiasis could be controlled in this way. At first, the residual insecticides like DDT and later Dieldrin were used against *Glossina* spp. Drawbacks are serious and numerous. These compounds are not easily biodegradable and therefore persist in the environment for a considerably long time. In this way, they can accumulate in the food chain. A large number of non-target organisms are thereby killed. Insecticide action, moreover, may kill off natural predators; as a result, a short time after the intervention there may be a larger population of tsetse than before. Lambwe Valley in Kenya is a good example. 100% kill can never be achieved through the use of insecticides, despite claims of successful tsetse (eradication) by this method, particularly along the margins of the tsetse distribution in Southern Africa and Northern Nigeria. Aerial spraying of chemical insecticides represents particularly unjustifiable high cost technology. Besides its serious environmental drawback, this spraying is beyond the reach not only of peasant farmers but also of most African countries.

Impregnated Screens/Traps/Targets

In the absence of adequate resources and sophisticated equipment, what solutions can be adopted that are effective, rapid and non-polluting? Careful field studies had earlier shown that many tsetse attracted to traps do not enter, but simply land on the outside. Thus, an insecticide-impregnated screen can significantly reduce initial densities when urgent action is needed to interrupt trypanosomiasis transmission (Laveissiere and Couret, 1980). What is needed for this is an efficient low dose insecticide. The pesticide should have a very strong effect during a presumably short contact period. Currently, only synthetic pyrethroids (deltamethrin) meet these requirements. They are however, expensive, but this is offset by the fact that low doses are used. In 1978, biconical trap impregnated with insecticide against riverine tsetse rekindled interest in this technique. A series of new trap designs were consequently produced, monoconical (Lancien, 1981); pyramidal (Gouteux and Lancien, 1987) and "Vavoua" (Laveissiere and Grebaut, 1990).

Live Targets

The use of pesticide-treated cattle as natural baits against tsetse was first tried some 40 years ago using DDT (Burnett, 1954). It was soon realised that persistence of DDT on cattle was not satisfactory, as it was easily rubbed off by vegetation and retreatments were necessary. The insecticide-treated cattle approach was later reactivated in Zimbabwe in the mid 1980s (Thomson, 1985); this time using pyrethroids. Cattle were dipped in deltamethrin "Decatix", dipwash or treated with a 1% deltamethrin "Spoton" pour on. A 5% suspension concentrate is used at a dipwash replenishment concentration of 0.0045% a.i. Deltamethrin pour on is applied at the rate of 1 ml per 10 kg body mass. Using these methods, workers in Zimbabwe showed that within 11 months after the start of tsetse control, no trypanosomes could be detected in cattle.

In communities where cattle dipping is a routine procedure for tick control, this technique may be incorporated as one measure of tsetse control. However, where dip tanks are not available, the method cannot be recommended on account of the expenses involved.

Community Participation

Tsetse control techniques enumerated above have not brought about significant changes to tsetse distribution over the last 40 years. Chemicals offer at best only short term solutions; research has indicated that in many cases, tsetse re-invade cleared areas very soon after the spraying campaigns. A different approach is obviously required, not only at the level of efforts by national and international agencies, but more importantly in the area of building grassroots capability to combat the fly at the subsistence farmers level.

Certain considerations associated with the nature of the tsetse problem and the available tsetse control measures require that a community participatory component is essential for effective control. In the first instance, no safe and affordable solution has yet been developed that would ensure the eradication of tsetse. This means that whatever measures are instituted will require to be sustained over a long period. Secondly, besides the advantage of reduced costs by sharing these with the beneficiaries, community participation facilitates collective and wide scale approach that is crucial for effective control.

It is important to note that no matter how technically efficient the means of control, the long term effectiveness of the measure is lost unless there is the means to sustain it. Mckelvey (1973) has cited a case where a low cost and efficient control measure proved to be ineffective for this reason. Community participation is one known cost-effective means of sustaining a technology which requires a large number of users and a period of time to have an impact. To include this component, however, it is necessary to consider what the adoption of the technology entails from the point of view of the user, and the practical and rational options available to him when confronted with the technology. Moreover, it is also necessary to consider the social organisational or institutional bases for participation. Rogers (1972) has suggested that there are different bases on which individuals or households may participate in collective activities. They may participate on the basis of "optional" decisions where, as individuals, they may choose out of their own volition to be part of communal action. Alternatively, they may participate on the basis of "authority" decisions, where administrative or other coercive force is used to induce people to take part in collective action. Finally, people may participate on the basis of "collective" decision where they choose voluntarily, as a body or bodies of persons, to act jointly to achieve some perceived common good.

Clearly, some approaches are more desirable than others in terms of long term commitment to the activity. It is important to note that whatever approach is adopted has implications for the long term sustainability of interest in the activity. However, the non-coercive bases for action depend on the existence of certain conditions. Important among these is whether or not the recipients perceive the problem to be solved as a felt need. In the case of tsetse, the problem may be such that any effort to solve it is sufficient to motivate people into collective action. However, where awareness of the vectorial role of tsetse is insufficiently understood, it may be necessary to integrate the control measures into some other activity geared towards solving their more immediate problem. Secondly, while the cost of the technology may itself be low, it may still be unaffordable in terms of the people's incomes. Moreover, the motives people have for keeping livestock, and their perceptions of the economic costs and benefits of adopting any control technologies are important considerations for the success of any voluntary community-based control measure.

Thirdly, all economic activities have social implications, particularly in rural peasant communities. It is necessary to ensure that whatever social costs incurred in the process of technology adoption do not outweigh the economic benefits as the users themselves perceive them.

Finally, it is important to consider the broad institutional contexts of technology promotion. In particular, it is important to consider the role of local political administrative structures and extension services in providing the needed structural bases for sustained control. In that case, the adoption of trapping technology at this level may involve the transfer to the extension services, the task of integrating the technology into the people's production and vector control system.

Failure to take these factors into account may lead to the abortion of attempts at technology transfer, or collapse due to inability to sustain the measures. This may occur despite the technical viability of the technology. Laveissiere (1980), for instance, describes a case in Côte d'Ivoire where, within 21 days, some 3671 farmers made 38,500 screens to be deployed in an area covering 15,000 km^2. Asserting the simplicity involved in making, and installing the traps, he says "... all that is needed is equipment and keeping the villages informed..." However, he qualifies his own assertion by citing cases of wilful fires and bush fires in the same location, which he considered to be a disadvantage to the use of traps. Moreover, he points out the reluctance of farmers to undertake treatments outside their own property, considering this to be the responsibility of the government.

Although community participation appears to be the ideal approach because of the nature of the available technologies and resources, it is not easy to achieve. As suggested above, there is need for community institutions or organisational structures to manage the operation of the control activities to ensure that they are sustained long enough for the benefits to be realised. Most areas where tsetse is a problem, however, are occupied by farmers whose peasant system of production is characterised by considerable individual and household autonomy. This presents problems when attempts are made to initiate and sustain activities at the communal level. Gouteux *et al.* (1990), for example, note that participation by rural farmers in the Congo was poor. More critically, however, they observed that the community lost interest in control as the number of flies decreased. In the urban areas and in some villages, the participation was a total failure.

It may be useful, on the other hand, to consider ICIPE's experience in the light of these documented cases. Brightwell *et al.* (1987) described the development of low cost techniques (NG2B trap) for tsetse control that could be sustained by the community with minimum external inputs in terms of materials and expertise. (The trap is made of blue and black cloth with an upper cone of white muslin netting). Tsetse are attracted by the royal blue colour of the trap exterior and are then attracted upwards into the netting cone by the light and then into a polythene bag cage at the top. Trapped flies die rapidly from heat stress in the cage and no insecticide is used. The efficiency of the NG2B trap at Nguruman is similar to that of the F3 trap designed by workers in Zimbabwe (Flint, 1985) but is much cheaper, with materials costing only about US $9. It is also very easy to make and can be put together in about 2 hours using a stapler. The cow urine used as baits were collected by the same people from their cattle. The advantage of this low technology approach is that management of tsetse control operations can be decentralised and local communities can be much more involved in tsetse control with government extension services having primarily an advisory role. Moreover, these traps have an advantage over targets in that they can be seen to be killing tsetse and this evokes tremendous enthusiasm (Dransfield *et al.*, 1990). Full community support is essential if losses from damage and theft are to be kept to a minimum. After brief training sessions, the people were able to make all the traps in their homesteads while also collecting from their herds the urine that was used as baits. Initial indications from this experiment, involving pastoralist Maasai organised as a group ranch, indicate that there was enthusiastic and informed participation at all levels. It needs to be pointed out, however, that certain socio-economic conditions augured well for this project and contributed to the obvious initial success. The first is the fact that livestock rearing constitutes the predominant — and for some the sole —means of livelihood. Secondly, the farmers participating in this project were already organised as a group ranch — with established leadership and a form of corporate interest in controlling tsetse in an area covering over 100 km^2. Nevertheless, the experiment demonstrated that given the right conditions, it is possible to successfully institute community-based tsetse control. While learning from the mistakes of the projects which have failed, it is also useful to seek to understand why this particular one succeeded. This will facilitate the recreation in those areas where similar activities are anticipated the conditions which contributed to this success.

REFERENCES

Brightwell, R., R. D. Dransfield , C. Kyorku , T. K. Golder , S. A. Tarimo and D. Mungai (1987). A new trap for *Glossina pallidipes*. *Trop. Pest Manage.* 33, 151–159.

Burnett (1954). The effect of poison bait cattle on population of *Glossina morsitans morsitans* and *G. swynnertoni*. *Bull. ent. Res.* 45, 41.

Dransfield, R. D., R. Brightwell , C. Kyorku and B. Williams (1990). Control of tsetse fly (Diptera: Glossinidae) populations using traps at Nguruman, South West Kenya. *Bull. Ent. Res.* 80, 265–276.

FAO (1979). Report of the Second Consultation on the Programme for the Control of African Animal Typanosomiasis. 5–7th Dec. 1978, Lusaka.

Gouteux, J. P. and J. Lancien (1986). Le piege pyramidal a tsetse (Diptera, Glossinidae) pour la capture et la lutte. Essais comparatifs et description de nouveaux systems de capture. *Trop. Med. Parasitol.* 37, 61–66.

Gouteux, J. P., F. Noireau, D. Sinda et J. L. Frezil (1990). The use of the pyramidal trap by rural communities in the Congo of sleeping sickness — Results of trials conducted in the Congo. *International Scientific Council for Trypanosomiasis Control and Research, 20th Meeting,* pp 428–435, Mombasa.

Jordan, A. M. (1988). The role of tsetse in African trypanosomiasis in livestock production in tsetse affected areas of Africa. *ILCA/ILRAD Publication.*

Lancien, J. (1981). Description du piege monoconique utilize pour l'elimination des glossines en Republique populaire du Congo. *Cah. ORSTOM. Ser. Entomol. Med. Parasitol.* XI, pp 235–238.

Lancien, J., J. P. Eouzan, J. L. Frezil et J. Mouchet (1981). Elimination des glossines par piegeage dans deux foyers de Trypanosomiase en Republique populaire du Congo. *Cah. ORSTOM Ser. Entomol. Med. Parasitol.* XIX, pp 239–246.

Laveissiere, C. et P. Grebaut (1990). Recherches sur les pieges a glossines (Diptera, Glossinidae). Mise au pount d'un modele economique: le piege "Vavoua". *Trop. Med. Parasitol.* 41, 185–192.

Laveissiere, C., J. P. Gouteux et D. Couret (1980). Essais de methods de lutte contre les glossines en zone preforestiere de Côte d'Ivoire. 1. Presentation de la zone, du materiel et des methods. *Cah. ORSTOM Ser Entomol. Med. Parasitol.* XVIII, pp 229–244.

Mckelvey, Jr. J. J. (1973). *Man Against Tsetse.* Cornell University Press, Ithaca & London.

Thomson, M. C. (1985). The effect on tsetse flies (*Glossina* spp) of deltamethrin applied to cattle either as a spray or incorporated into ear-tag. *Trop. Pest. Manage.* 33, 329–335.

Rogers, E. M. (1972). Key concepts and models. In *Inducing Technology Change for Economic Growth and Development* (Eds. R. A. Solo and E. M. Rogers), Michigan State University Press.

World Bank (1990). *World Development Report, World Development Indicators.* Oxford University Press.

Community-Based Control of Livestock Ticks in Nigeria

F. O. Ayanwale

Department of Veterinary Public Health and Preventive Medicine,
University of Ibadan, Ibadan, Nigeria

SUMMARY

The abundance of livestock ticks in the tropics contributes to the low productivity of food animals in Africa. Harsh climatic conditions which are conducive to the massive proliferation of the ticks transmit the diseases that decimate African cattle. Livestock farmers know *Boophilus* species, *Amblyomma, Rhipicephalus, Argas* and other ticks. They can recognise diseases like East Coast fever, theileriosis, heartwater (cowdriosis), streptothricosis (Kirchi) and piroplasmosis which they cause. They also know the traditional and modern remedies for them. However, the costs of drugs and modern tickicidal products made from synthetic organophosphates or natural products like pyrethrins and administered in form of sprays, dips, washes or pour-on are far beyond the reach of African livestock farmers. Instead, community-based methods used in controlling ticks are now being explored and encouraged. The ecological approach adopted by the herdsmen involves strategic grazing of livestock during the rainy season when ticks are in abundance, early bush burning, deforestation of natural vegetation, cultivation of its soil and improvement of pasture, all of which lead to the destruction of ticks, at these areas of human activities. The Fulani herdsmen also do hand-deticking of their stock. Twenty or more members of the cooperative societies would visit members' herds in turns to physically detick the animals. Some groups contribute money to buy hand pumps which spray locally prepared tickicidal solutions made from herbs and other African plants. "Native intelligence" of the livestock farmers involves vaccination of their animals with crude tick-gut extract. They use palm kernel oil base locally called *adin* as the active immunomodulator or an incomplete adjuvant to increase the immune response of the animals to the "vaccine" applied by laceration incision.

Finally, biological control of ticks where natural predators like ox-peckers, lizards, ants and even white egrets are used is discussed.

INTRODUCTION

The increasing protein deficiency gap of most Africans is still a major concern to the continent. Beef, milk, chicken and eggs are no longer foods for the common man. Demands so far exceed supplies that only the rich can afford. The productivity of livestock in Africa, particularly of cattle, is very low. The reasons for this include harsh climatic conditions, poor husbandry management, low level of education on the part of the traditional pastoralists who constitute the largest percentage of cattle producers in the continent. Comparatively poor genetic factors of the indigenous breeds, variety of other environmental factors which include high temperature and humidity, seasonal shortage of feed and water, unchanging nomadism, viral, bacterial, rickettsial and above all endo- and ecto-parasitic diseases are other important factors of concern to the continent.

The indigenous African cattle that originated from the crosses of humpless Hemitic longhorn (*Bos taurus longifrons*) which arrived in Africa 5000 BC (Mukasa, 1989), the humpless shorthorn (*Bos taurus brachyceros*), and the humped zebu (*Bos indicus*) have essential adaptive genetic traits which include resistance to or tolerance of pest and diseases, tolerance of intense heat and humidity and ability to utilise high-fibre forages. However, the problems created by ever-present and intractable ectoparasites and in particular the tick-associated diseases like East Coast fever, theileriosis, heartwater or cowdriosis, Kirchi, dermatophilosis, babesiosis etc. are major common problems that African countries have to address now, if such needed animal protein from meat and milk is to reach African populations.

Over the years the native African breeds of cattle like N'dama, White Fulani, Red Bororo, Kuri, Senegal Fulani, Boran, Angoni, Bambara, Ankole, Danakil, Tuli, Basuto, Africander, Mashona, Keteku and Sokoto Gudali have encountered many of those tick-associated diseases mentioned above. Cattle owners can recognise the diseases, they identify their causative tick agents like *Boophilus*, *Rhipicephalus*, *Amblyomma*, *Hyalomma* and the *Ixodes* and they also have their own native methods of control of the ticks and treatments of the diseases that they cause. The fowl ticks, *Arga persicus*, spinose ear ticks, *Otobius megnini* of horses, sheep, goats, and even pigs are well known to the livestock farmers. The different remedies applied by the farmers, however, have not been well documented. It is therefore the responsibility of African scientists to research into these remedies and to link them with the modern and sophisticated application of vaccines, acaricides and other recent "pour-on" tickicidal products as necessary.

This paper therefore presents a note on community-based control of livestock ticks being practised by the Fulani herdsmen in Nigeria.

CHICKEN TICKS CONTROL BY NATURAL SELECTIONS

The most pathogenic chicken tick is *Argas persicus* locally called *egbon adie*. In most African countries certain indigenous breeds of chicken (*Olopi* or local *Kasa*) show a high degree of tolerance to this ectoparasite. They also exhibit high disease resistance and also can withstand the harsh conditions of humidity and high temperatures. Anatomically, these types of chickens possess long tiny legs, long sharp talons and scanty feathers. They have lower bodyweight, light bones and can run fast on ground. Community farmers are advised to buy chicken with those features. Some breeds of this indigenous chicken may not have feathers on their neck at all (the *Olopi* chicken), they not only tolerate heavy infestation of *Argas persicus* they also eat less food and produce about ten eggs that would hatch black chicks at one time of reproduction. These black chicks have the characteristics of seeking and pecking at ticks that could be found on their mother's body. They also preen one another with their beaks. They are predatory on all ticks and lice that can be found within their population. These indigenous birds also are known not to come down easily with reputable diseases like Newcastle, Gumboro or fowl pox. Coccidiosis does not even bother them. The chicks are hatched black or mottled in colour and they are, therefore, not easily seen by the hawks unlike the white-coloured chicks produced by imported birds. Further advantages of these native birds are that they would attack other prey birds like hawks and even man that threatens their young chicks with their sharp talons and beak. *Olopi* birds are known to have even confronted and killed snakes that disturb them during brooding period. Most Nigerian backyard poultry keeping communities rear these types of chicken and sell good ones to one another to popularise and increase the progeny. An added advantage of this indigenous bird is their ability to eat high fibre foods. They subsist on termites, cassava fibres, coconut and palm kernel fibres, they eat earth worms, cockroaches and even grasshoppers, thus not only reducing competition in food with man and other livestocks but also serving as scavengers of those crop pests.

CATTLE TICKS CONTROL

90% of Africa's estimated 200 million cattle has been reported to be infested with ticks of different species. Half of the US $7,000 million global loss in livestock production is from Africa because of the diversity of tick species and number of animals infested (Dipeolu, 1989). The same author estimated the cost of acaricides being used to control the tick menace as US $720 million per annum in Africa. Apart from the high costs of acaricides which few African farmers can afford, these organophosphate products are hazardous to the animals, man and also to the environment. The chemicals destroy other beneficial organisms in pasture. They kill fishes in the water into which the chemicals are eventually washed (Ayanwale, 1990). Apart from these, certain acaricides remain as chemical residues in animal products like milk and meat meant for human consumption.

It was once believed that the age of cattle at puberty (Table 1) was an important determinant of reproductive efficiency. Several studies, however, have shown that the major factors controlling the onset of puberty are genetic

Table 1. **Some estimates of age at puberty among *Bos taurus* cattle and their crosses with *Bos indicus* types in the tropics and subtropics**

Breed	Location	Estimates (months)	Source
Brown Swiss	Rwanda	8–15	Compere (1963)
Jersey	India	14.1 ± 0.14	McDowell *et al.* (1976)
Angus	USA	14.4	Reynolds *et al.* (1963)
$^3/_4$ *Bos taurus* cross	India	14.5 ± 0.23	McDowell *et al.* (1976)
Brahman x Angus	USA	15.3	Reynolds *et al.* (1963)
$^1/_2$ *Bos taurus* cross	India	15.3 ± 0.23	McDowell *et al.* (1976)
$^1/_4$ *Bos taurus* cross	India	16.8 ± 0.46	McDowell *et al.* (1976)
Brahman x Shorthorn	Florida (USA)	17.0	Plasse *et al*.(1968a)
F_1 crosses	Ethiopia	17.0 ± 1.5	Aberro (1983)
Africander x Andus	USA		
$^3/_4$ Friesian x $^1/_4$ Zebu	Trinidad	19	Duckworth (1949)
Brahman	Florida (USA)	19.4	Plasse *et al.* (1968a)
Pure Friesian	Nigeria	19.5	Knudsen and Sohael (1970)
$^3/_4$ Friesian x $^1/_4$ White Fulani	Nigeria	20.0	Knudsen and Sohael (1970)
$^1/_2$ Friesian $^1/_2$ White Fulani	Nigeria	21.2	Knudsen and Sohael (1970)
Crossbreeds	South America	22.5	Linares *et al*. (1974)
Brahman x Criollo	South America	23.3	Ordonez *et al.* (1974)
Crossbreeds	Somalia	24.5	Aria and Cristofori (1980)
Ankole x Jersey	Rwanda	26.5	Compere (1963)

Source: Mukasa-Mugerwa (1989)

makeup, body weight and growth as a result of good nutrition rather than age (Swensen *et al.*, 1981; Boyd, 1977; McDonald, 1980). So until heifers reach a particular target or critical weight, oestrus is not likely to occur. Zebu animals commonly found in Africa reach puberty 6 –12 months later than *Bos taurus* cattle (Warnick, 1965; Wiltbank *et al.*, 1966). It has been shown that poor nutrition and the use of acaricides as seen in Table 2 further delays puberty in African cattle. The need therefore to explore and improve the community-based traditional control of livestock ticks as alternatives to modern acaricides cannot be over-emphasised.

Table 2. Effect of acaricide and anthelmintic treatment on age and weight at puberty

Treatment	*n*	Number attaining puberty	Age (days) Mean	Age (days) Range	Weight (kg) Mean	Weight (kg) Range
No treatment	50	45	557	413–735	253[a]	158–338
Acaricide	56	47	533	328–760	253[a]	169–330
Anthelmintic	50	50	511	390–670	262[ab]	169–398
Anthelmintic + acaricide	56	55	522	340–735	274[b]	163–360
Overall	212	197	530	328–760	261[b]	158–360

In the mean weight column, means without at least one common superscript are different ($P < 0.05$).

Source: Modified from Post and Reich (1980) by Mukasa-Mugerwa (1989)

The nomadic Fulani's "native intelligence" which their communities for generations have practised to control livestock ticks are:

1. Ecological approach

   (a) Strategic grazing of stock during the rainy season

   (b) Early bush burning during the dry season

   (c) Application of particular plant extracts as spray to repel or destroy ticks.

2. Hand deticking

3. The use of herbs

4. Native vaccination with *adin* as adjuvant or immuno-modulator

5. Biological control

   (a) Use of attractants for natural predators of ticks like ants, spiders, lizards, oxpeckers and white egrets.

ECOLOGICAL APPROACH

During the rainy season grass, water and milk are abundant. Ticks also tend to be in abundance but farming activities disturb this. The nomads take advantage of the approaching rainy season to cultivate the land around their temporary settlement. Deforestation, clearing and burning of grass destroy the free-living ticks. Other tick hosts like rats, carnivores, porcupines and wild ungulates disappear further into the bush away from man.

With early morning activities of farming, farmers tether their animals to trees and stumps, the wives milk the cows for sale, children are sent to the newly-established nomadic education schools while the father after tending the crops, returns to his hut to catch up with rest from his previous long nomadic journey while awaiting the return of the children from school. In the mid-day, the cattle are released and allowed to graze at restricted community grasslands under the supervision of the children. The occasional ticks that have escaped destruction by burning and succeeded in attaching themselves to cattle can be seen and hand picked off the animals by the children.

HAND-DETICKING

The nomadic Fulani livestock farmers when they are not on the move often organise community meetings, usually in the early evening times to share experience that would improve their stock. Places of meetings rotate from one herd to the other. Active hand deticking of each herd is done by the co-operative groups of 10, 15 or 20 men. Some cooperative livestock farmers buy hand pumps and acaricides in order to spray their own herds against ticks. From our experience, only one-host ticks are effectively controlled by this hand spray method. The need for weekly spraying of cattle particularly against 3-host species could not be met by these peasant farmers who do "once and for all" seasonal spraying only. This latter group, however, resort to the use of other native medicine.

THE USE OF HERBS

Africa is endowed by nature with an abundance of plants. Many of these plants have pharmacological and toxicological properties which the livestock farmer uses for therapeutic, prophylactic and even aphrodisiac purposes both on himself and his livestock. Some of these plant extracts are used as tickicidal substances. Some herbs are known to have antidotal properties to the neurotoxic salivary secretion of *Ixodes* ticks which cause flaccid paralysis of sheep. The reversal effects are known to be so spontaneous that it could be compared with the most potent antitoxoid injectable found in the market today. The plant is locally called *ikunmu-apado*. The botanical name is unknown. The roots and leaves produce an atropine-like substance which is poisonous. 0.01 gm of this mixture would destroy ticks in a second. Further, there are other varieties of these plants which go by different local names. The most common ones are the Cinchona, belladona, the oriental and desert poppies. The plants' extracts are alkaloids of different toxic strengths. They use locally brewed alcohol (*Apeteshi*, push me and I push you, *Tombo*) and other solvents to mix them up for use as tickicidal products. Some are smeared on the animals to repel ticks from attaching. Those attached already may fall off.

NATIVE VACCINATION

A practice common among the Fulani medicine is to incise any part of the body that is "diseased", in order to let out the bad blood and apply a medicament. So when a cow is dead or sick of a disease suspected to be tick-associated in a flock, the farmer picks off all engorged ticks upon the dead animals, crushes them in a mortar, stone or dish, removes the cuticular debris and mixes the gut content with ashes, palm-oil or kernel extract called *adin*. He then incises the acapular or neck region of the remaining herds with a razor blade or sharp knife and rubs in the paste.

In scientific terms, this is a form of vaccination where polyvalent antigens (gut extract) mixed with an active immunomodulator or an incomplete adjuvant (*adin*) had been used. Active immunomodulation is a term used when an attempt is made to influence the immune system without changing the functional capacity of the antigens. In other words, the adjuvant (*adin*) only helps to increase the immune responses of the animals to the antigens. By performing firstly the vehicular function or an inert carrier of the antigen, this vegetable oil adjuvant secondly makes a depot formation of the vaccine at the site of administration. Thirdly, it delays antigen absorption, thereby leading to sterile inflammatory process which triggers off the inherent activities of the lymphocytes, monocytes, macrophages and other immune responses which on the long run protects the animal against those specific diseases.

BIOLOGICAL CONTROL OF TICKS

The most effective method to control the livestock tick is to break its life-cycle. This may be achieved by either preventing the engorgement of the adult tick, interrupting the feeding phase or preventing the attachment of free-living larvae or nymphs. The use of natural predators is perhaps the cheapest means of achieving this. The Fulani nomad throws a few grains of millet, maize or guinea corns around the enclosures of his cattle. These attract local chicken, other birds, rats and lizards which after eating the grains would see the attached ticks on the animals and feed upon them. Nomads encourage birds like *Buphagus*, ox-peckers and the white egrets to follow their stocks. These birds actively seek and feed on the ticks as well.

One other interesting practice of the nomad community is that they mix *gari*, a staple Nigerian food made from cassava with granulated sugar. They then sprinkle this near the termite hills, land cracks and other natural microhabitats of ticks that can be found around the cattle paddocks in order to attract ants that would also feed on the ticks.

In confirming the relevance and comparative advantages of these native and community-based control of livestock ticks, African scientists should be encouraged to research into and improve this cultural heritage of African livestock medicine. The potential of the African scientists in this direction is not in doubt. The achievements of the founders and staff of ICIPE in Kenya and their collaborators within and outside Africa are definite proofs that Africa's economic development can be science-led without losing its social and cultural values.

ACKNOWLEDGEMENT

I wish to thank the organisers of this conference and the director of ICIPE, Professor T. R. Odhiambo for their support.

REFERENCES

Ayanwale, F. O. (1990). The status of cellular immunity in tick control research. In *Proceedings of the International Tick Symposium ICIPE, Nairobi, Kenya*. (In press).

Boyd, H. (1977). Anoestrus in cattle. *Vet. Record* 100, 150–153.

Dipeolu, O. O. (1989). Overview of livestock ticks research programme (LTRP) at ICIPE, Nairobi, Kenya. 45 pp.

McDonald, L. E. (1980). *Veterinary Endocrinology and Reproduction*. Lea and Febiger, Philadelphia, USA, 560 pp.

Mukasa-Mugerwa, E. (1989). A review of reproductive performance of female *Bos indicus* (Zebu) cattle. *ILCA Monograph* No. 6, 134.

Post, T. B. and M. M. Reich (1980). Puberty in tropical breeds of heifers as monitored by plasma progesterone. *Proceedings of the Australian Society of Animal Production* 13, 61–62.

Swenson, C., J. Scharr, E. Brannang and L. B. Meakel (1981). Breeding activities of the Ethio-Swedish Integrated Rural Development Project III. Reproductive performance of zebu and crossbreed cattle. *World Anim. Rev.* 38, 31–36.

Warwic, A. C. (1965). Reproduction and fertility in beef cattle. In *Beef Cattle in Florida*, pp 59–68, (Eds. T. J. Cunha and G. N. Rhodes), Florida Department of Agriculture.

Wiltbank, J. N., K. E. Gregory, L. A. Swinger, J. E. Ingalla, J. A. Rothlisberger, and R. M. Koch (1966). Effect of heterosis on age and weight at puberty in beef heifers. *J. Anim. Sci.* 25, 744–751.

Crop Losses and Economic Injury Level in Relation to IPM of the Stem Borer *Chilo partellus* in Maize in Kenya

K. V. Seshu Reddy and K. O. S. Sum

The International Centre of Insect Physiology and Ecology (ICIPE),
P. O. Box 30772, Nairobi, Kenya

SUMMARY

The paper describes the information generated on the magnitude of grain yield losses caused by the stem borer, *Chilo partellus* (Swinhoe) in maize in Kenya. The economic injury level (EIL) of the stem borer was determined by artificially infesting KRN-1, a tolerant maize cultivar, at four different growth stages viz., 21, 28, 35 and 42 days after emergence, with 0, 2, 4, 6, 8 and 10 neonate larvae/plant. There was maximum grain yield reduction, leaf damage and stem tunnelling in younger plants. Higher larval densities gave higher grain yield reduction irrespective of crop stage and the EIL increased with increase in crop growth stages and costs of control.

INTRODUCTION

Information on the yield losses suffered by different crops due to pests has been reported by various workers from time to time (Chiarappa, 1971; Teng, 1987). The losses vary from crop to crop, insect to insect and between locations and seasons. However, some of the reports are only based on rough estimates or even guesses; data on crop losses are sparse and much of what is available is unreliable. There is thus a great need for quantitative crop loss assessments (CLA) which helps in successful and effective decision making in integrated pest management (IPM) strategies. It is also important to have a knowledge of how the losses due to insect pests may vary with different factors such as phenological stages of a crop, as well as crop cultivars.

One of the crucial requirements for generating valid information on quantitative losses in crops due to pests is the accuracy of the assessment method used. Different methods have been used by different workers to assess such losses and these methods vary according to the crops and pests (Chiarappa, 1971; Walker, 1983; Teng, 1987; Seshu Reddy, 1988).

A simple method is to compare the average yield of individual plants free from natural infestation by pests with that of infested plants in a field.

Crop losses are often assessed by comparing yields from plots treated with a pesticide with yields from untreated plots.

A common method is to use artificial infestation to achieve different levels of attack/damage by target pest(s). Another method is to simulate the loss of roots, leaves or plants by artificial removal or damage and then compare yields with the undamaged plants.

Insect susceptible and resistant cultivars may also be used to obtain different levels of infestation and damage and then compare the yields.

All methods mentioned above have their own merits and limitations. There is, therefore, a need for simplifying and standardising these methods so that the information generated in different regions/countries can be compared.

ECONOMIC INJURY LEVEL

The crop losses caused by insect pests expected by a farmer are a component, among other factors, in the determination of a threshold level at which control action is taken, and this is known as the economic threshold (ET) or action threshold (AT). As the infestation increases with time, the control measures must be taken at ET level to prevent further increase in the pest population from reaching the economic injury level (EIL) (Walker, 1983).

In the current literature, information on the practical determination of EIL for major insect pests and crops like maize is meagre. It is the aim of the present study to determine the EIL for the stem borer, *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) in maize in Kenya.

MATERIALS AND METHODS

Adopting the artificial infestation method described above, the EIL was determined in maize cultivar KRN-1 (a stem borer tolerant cultivar) with plants in cages (dimensions of 5 x 4 x 2.5 m for length, width and height, respectively). The cages were covered with mosquito netting soon after crop emergence to avoid external infestation. The experiment was laid out in a randomised complete block design with three replications. In each cage, there were six rows of plants planted at a spacing of 30 cm between plants and 75 cm between rows. Each row was infested with newly hatched *C. partellus* larvae at the rate of 0, 2, 4, 6, 8 and 10 per plant, each level representing a treatment at 21, 28, 35 and 42 days after crop emergence (DAE). The zero density was represented by the uninfested control.

As a way of assessing the stem borer damage on the leaves, observations were taken on four randomly sampled plants/row (treatment) and their foliar damage was rated on a 1–9 scale; rating 1 was given to healthy leaves (no damage symptoms), 2–3, given to leaves showing low intensity of damage, while 4–5 and 6–9 represented medium and high intensity damage symptoms respectively. Larval establishment/survival was also monitored in the same period by destructive sampling of three randomly selected plants per treatment.

At harvest, data was collected on grain yield, and other damage parameters such as stem tunnelling, exit holes and internodes bored and these were subjected to statistical data analysis.

An attempt was also made to understand the yield - infestation relationship based on testing three forms of equation i.e. linear ($y = a+bx$), log linear ($\log y = \log a + b \log_x$) and quadratic ($y = a + bx + xc^2$) where y = grain yield and x = larval density. The determined relationship (model) together with the costs of crop protection of three commonly used insecticides for stem borer control (i.e., Thiodan 3%G, Dipterex 2.5% G and Furadan 5G) put in the leaf whorl twice at the rate of 0.5 g/plant (fingerthumb pinch) were integrated and used to compute the values of EIL as shown in the formula:

$$\text{EIL} = \frac{\text{Cost of insecticidal treatment/ha}}{\text{Cost of maize grain per kg} \times b}$$

where b = regression coefficient.

RESULTS AND DISCUSSION

Larval Density, Crop Growth Stages and Grain Yield

Larval density and crop growth stages were observed to be significant sources of variation in the ultimate yields realised. A maximum of 65% grain yield reduction occurred at 21 DAE (youngest plants) when infested with 10 larvae/plant, the highest density. Grain yield reduction was directly proportional to the larval densities infested and inversely proportional to the crop growth stages (Table 1).

Table 1. **Percentage net grain yield loss in maize (KRN-1) due to varying larval densities of *C. partellus* at different crop growth stages**

Crop stage	Larval density	Grain g/plant	Yield kg/ha	Reduction in grain yield	Reduction in g/y kg/ha	Net loss Ksh.
21 DAE	2	170.43B	7574.6	18.90	1758.64	7034.56
	4	140.06C	6225.1	33.30	3108.14	12432.56
	6	122.37C	5438.6	41.70	3894.64	15578.6
	8	98.23C	4362.7	53.20	4967.54	19870.16
	10	73.37E	3260.86	65.00	6072.38	24289.52
	Control	210.00A	9333.24	0.00	0.0	0.0
28 DAE	2	196.46A	8731.47	6.40	601.77	2407.08
	4	167.43B	7441.26	20.30	1891.98	7567.92
	6	139.80C	6213.27	33.40	3119.97	12479.92
	8	124.67C	5540.83	40.60	3792.41	15169.64
	10	104.00D	4622.18	50.40	4711.06	18844.24
	Control	210.00A	9333.24	0.00	0.0	0.00
35 DAE	2	210.63A	9361.24	0.0	–28.0	–112.0
	4	203.33A	9036.80	3.2	296.44	1185.76
	6	163.33B	7259.04	22.2	2074.20	8292.80
	8	144.31BC	6413.71	31.2	2919.53	11678.12
	10	132.47C	5881.5	36.9	3451.74	13806.96
	Control	210.00A	9333.24	0.00	0.000	0.0
42 DAE	2	218.22A	9703.43	0.0	–370.21	–1430.84
	4	206.83A	9192.36	1.5	140.89	563.56
	6	181.67B	8074.14	13.5	1259.10	5036.40
	8	161.51BC	7180.82	23.0	2152.42	8609.68
	10	154.00C	6844.40	26.7	2488.84	9955.37
	Control	210.00A	9333.24	0.0	0.0	0.00

*Means in the same column followed by same letter are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5% level.

Similar trends have been observed by other workers including Seshu Reddy and Sum (1991) in their work on Katumani maize cultivar and Sharma and Sharma (1987) with Basi Local and Cm-500 maize cultivars, though with differences in magnitudes of yield reduction. The inverse response of yield reduction to crop growth stage at the time of infestation could be explained by the fact that there is increased toughness of leaves and stem with advancement in crop stage. Hence, it became difficult for the neonate larvae to thrive on them well, whereas in younger plants the larvae could feed well on the soft tissues and for a longer time (Sharma and Sharma, 1987).

Foliar Damage, Stem Tunnelling and Grain Yield Loss

These were some of the damage parameters taken during the study. Foliar damage based on the 1–9 rating scale, was generally on the lower side of the scale i.e. ($x \geq 2.37 \leq 2.72$) for the four growth stages (Table 2). However, there

Table 2. **Mean stalk damage and foliar rating due to different infestation levels of *C. partellus* in relation to crop growth stages in maize**

Crop stage	Larvae	Mean % tunnelling	Mean foliar rating
21 DAE	0	0.00	1.0
	2	11.50	2.37
	4	13.13	2.60
	6	15.77	2.77
	8	18.43	2.87
	10	29.13	3.03
28 DAE	0	0.0	1.0
	2	4.57	2.20
	4	10.00	2.40
	6	12.07	2.60
	8	13.60	2.73
	10	15.80	2.93
35 DAE	0	0.00	1.0
	2	6.63	2.2
	4	7.23	2.43
	6	6.57	2.53
	8	13.17	2.60
	10	17.43	2.70
42 DAE	0	0.00	1.0
	2	4.07	2.1
	4	6.30	2.20
	6	9.37	2.41
	8	9.91	2.47
	10	15.73	2.63

was an increase in damage with increase in larval density, while the intensity of damage was greater on the younger plants (21 DAE) than the older ones. Correlation analysis (Table 3) showed the existence of significant negative correlations between foliar damage and grain yield. Similar correlations also

***Table 3*. Values of correlation coefficient of variables (parameters) at different crop growth stages of maize (KRN-1)**

Characters	2	3	4	5	6
21 DAE					
1. Plant height	–0.40799NS	–0.35751NS	0.5413*	0.61579**	–0.31259NS
2. Exit holes		0.73638**	0.64085**	–0.78049**	0.80630**
3. % Nodes bored			0.80231**	–0.83246**	0.093626**
4. % Stem tunnelling				–0.90994**	0.78784**
5. Grain wt./plot					–0.86799**
6. Leaf damage rating					
28 DAE					
1. Plant height	–0.03845NS	–0.14365NS	–0.43943NS	0.61992**	–0.35639NS
2. Exit holes		0.04990NS	0.21842NS	–0.19350NS	0.20389NS
3. % Nodes bored			0.84964**	–0.77008**	0.91299**
4. Stem tunnelling				–0.86665**	0.81849**
5. Grain wt./plot					0.84436**
6. Leaf damage rating					
35 DAE					
1. Plant height	0.12171NS	0.02791NS	0.09534NS	–0.027887NS	–0.10660NS
2. Exit holes		0.70607**	0.86232**	–0.7084**	0.89800**
3. % Nodes bored			0.77589	–0.57769**	0.80200**
4. % Stem tunnelling				–0.78082**	0.80330**
5. Grain wt./plot					
6. Leaf damage rating					
42 DAE					
1. Plant height	0.22853NS	–0.133355NS	0.18632NS	–0.13646NS	0.04180NS
	0.72010**	0.73238**	–0.56303*	0.70147**	
		0.71080**	–0.55457**	0.70142**	
			–0.71799**	0.79553***	
			–0.616 86**		

*Significant at 5% level, ** Significant at 1% level, NS Not Significant existed between stem tunnelling and grain yield at all the growth stages. Stem tunnelling was also found to be significantly dependent on the larval densities with the higher densities giving higher tunnellings.

The percentage grain yield loss was used to express the magnitude of direct loss on maize yield. It is the loss (w) in the presence of the pest and is expressed as a reduction in potential (pest free) yield (m) as percentage of it, i.e. $w = \frac{(m - y_1)}{m} \times 100$, where y_1 is the actual yield realised (Walker, 1987).

Table 2 shows that the amount of loss was actually influenced by the crop stage and larval density. Younger plants which had greater damage in terms of stem tunnelling and foliar damage also registered the highest percent losses. However, regardless of crop stage, percentage yield losses did increase with increase in larval densities.

ECONOMIC LOSSES

Preceding the determination of economic losses, the net monetary loss or gain due to the varying levels of larval infestation at different crop growth stage was computed (Table 1).

Table 4. **Regressions for the three forms of yield-infestation relationship tested**

DAE	Form of equation	Constant (a)	Regression coefficient x (b)	log x (b)	x^2 (c)	r^2
21	Linear	8945.69	–582.53			0.936
	Log linear	5.475527		–0.40359**		0.7483
	Quadratic	207.136905	–17.501012**		0.439435NS	0.9450
28	Linear	9434.13	–490.62**			0.956
	Log linear	5.461423		–0.278124**		0.8022
	Quadratic	213.471429	–11.9433**		0.090470NS	0.9567
35	Linear	9871.06	–397.73**			0.837
	Log linear	5.458679*			–0.190232**	0.6276
	Quadratic	215.595238	–4.0668572NS		0.488095NS	0.8581
42	Linear	98971.46	–301.86*			0.749
	Log linear	5.437406			0.130998**	0.5453
	Quadratic	215.915476	–1.707560NS		–0.508482NS	

** Significant at 1%, NS Not significant.

The monetary loss or gain was dependent on crop stage and larval density. The monetary loss due to the lowest density (2 larvae/plant) was least at 21 and 28 DAE while at 35 and 42 DAE there were no losses of the same density. When the larval density increased to 4 or more, there was a sudden increase in loss which ascended with the densities and maximum loss occurred with 10 larvae/plant irrespective of plant growth stage. Similar observations of increased monetary loss with increase in infestation were also made by Sarup *et al.* (1977), Sharma and Sharma (1987) and Seshu Reddy and Sum (1991) though there existed differences in the magnitude of losses. Such differences or variations could be a result of a number of biotic and abiotic factors which could influence the life cycle of the insect. Also differences in cultivars and agroecological zones may play an important part in influencing the infestation-yield relationship.

Decisions on pest control are based on the relationship between yield (y) and infestation (i) i.e. $y = f(i)$ (Walker, 1987). In order to achieve this, a regression of larval density (x) on grain yield (y) gave results which are shown in Table 4. Based on three forms of the equations tested, the coefficient of determination (r^2) for the quadratic form was higher than that of the linear and log linear, but the regression coefficient for this form was not significant either at 1% or 5%. However, there were relatively high r^2 values and significant coefficients of x for the linear form, than the quadratic and log linear forms, hence the linear form offered a more adequate explanation of the nature of the relationship. It was also observed that the nature of the relationship was never affected by the crop stage. The linear relationship indicates that the yield reduction is proportional to infestation and lack of compensation following increased attack (Walker, 1987). The negative coefficients of b for the independent variable x further confirms this assertion.

Table 5. **Economic injury levels of *Chilo partellus* in maize (KRN-1) calculated from the costs of protection of three insecticides applied twice and linear regression models of maize yield (y) kg/ha and larval density (x)**

Days after crop emergence (DAE)	r^2	$y = a + bx$	Economic injury level (EIL)		
			Dipterex	Thiodan	Furadan
21	0.936	$y = 8945.69 - 582.53x$	0.53	0.65	1.49
28	0.956	$y = 9434.13 - 490.61x$	0.63	0.77	1.76
35	0.837	$y = 9871.06 - 397.73x$	0.78	0.96	2.17
42	0.749	$y = 9897.46 - 301.36x$	1.03	1.26	2.85

Based on the determined linear relationships and costs of protection for three insecticides applied twice, the EIL values computed are presented in Table 5. It is observed from the table that EIL increased with increase in crop stage and costs of protection. But there are also other indirect factors which affect EIL such as nature of the pest, market price of the crop, etc.

ACKNOWLEDGEMENTS

The authors are grateful to Professor Thomas R. Odhiambo, the Director of ICIPE and Professor K. N. Saxena, Programme Leader, Crop Pests Research Programme, for their kind support and encouragement. Special thanks go to Dr. Morris O. Odindo for reading the manuscript and making suggestions for its improvement.

REFERENCES

Chiarappa, L. (1971). *Crop Loss Assessment Methods: FAO Manual on the Evaluation and Prevention of Losses by Pests, Diseases, Weeds.* FAO and CABI, Wallingford, UK. Looseleaf + 3 Supplements (Supplement 2, 1981, 123).

Sarup, P., V. K. Sharma, V. P. S. Panwar, K. H. Siddique, K. K. Marwaha and K.N. Agrawal (1977). Economic threshold of *Chilo partellus* infesting maize crop. *J. Entomol. Res.* 1, 92–99.

Seshu Reddy, K. V. (1988). Assessment of on-farm yield losses in sorghum due to insect pests. *Insect Sci. Applic.* 9, 679–685.

Seshu Reddy, K. V. and K. O. S. Sum (1991). Determination of economic injury level of the stem borer, *Chilo partellus* (Swinhoe) in maize, *Zea mays* L. *Insect Sci. Applic.* 12, 269–274.

Sharma, N. and V. K. Sharma (1984). Studies on the economic injury level in maize *Zea mays* L. to stem borer *Chilo partellus* (Swinhoe) (Pyralidae: Lepidoptera) in India. *Trop. Pest Manage.* 33, 44–51.

Teng, P. S. (1987). *Crop Loss Assessment and Pest Management.* APS Press, The American Phytopathological Society, St. Paul, Minnesota, 270 pp.

Walker, P. T. (1983). The assessment of crop losses in cereals. *Insect Sci. Applic.* 4, 97–104.

Walker, P. T. (1987). Quantifying the relationship between insect populations damage, yield and economic thresholds. In *Crop Loss Assessment and Pest Management*, pp 114 –125, (Ed. P. S. Teng), APS Press, Minnesota.

Role of Community Knowledge in Developing Integrated Pest Management in Africa

B. Amoako-Atta

Subregional Co-ordinator for West Africa
ABN/UNESCO
P. O. Box 16496
Accra-Airport, Ghana

SUMMARY

Many evolving components of pest management require elaborate understanding and manipulation to realise their maximum effects. The key to understanding the evolving or developing pest management system rests primarily on the perception of the pest problem, its ramifications on the defined target group and available management options accessible to contain the pest situation. The lack of carefully coordinated and integrated role of the defined target beneficiary on the various development stages of the pest management strategies is exposing the inadequacy or lack of adoption of most developed pest management strategies especially within most African tropical agricultural systems. In an environment where prevailing ecological factors seem to favour and perpetuate sustainable pest development cycles and where target communities in most need of pest management interventions are distantly placed from the researchers realm, and more seriously where knowledge, attitude and practices (KAP) of such target group on existing or basic elementary/fundamental pest management concepts supposed to be the building blocks for serious researcher effort and consideration, are not only scanty but have not been properly assessed and quantified, the need for re-orientation of research and development approaches to integrate fully the defined target groups, destined to benefit from any such developing pest management strategies, cannot be over-emphasised.

This paper emphasises the sequential process of analysing the factors that motivate or demotivate community interface with evolving technologies. A proper positioning of the community's perception of a pest problem, and better understanding of the options for such manipulation of the pest situation thus become the basic tenet for effective mobilisation for community action to manipulate pest problems. It is concluded that the community has an "animator" role to play in the development, adoption, and extension of an evolving technology.

INTEGRATED PEST MANAGEMENT (IPM) AS A CONCEPT

Integrated pest management as a concept is a pest management system that in the context of the environment and the population dynamics of the pest species, utilises all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic injury (FAO, 1966). This definition brings into focus the need for detailed understanding of the agro-ecosystem to permit the assessment of stabilising mechanisms operating on the pest within the agro-ecosystem so as to effectively harmonise various controlling techniques considered essential in order to prevent disruptive efforts in our attempt at controlling the pest. Ensuing from the above definition and boundaries of IPM, two major facets of IPM become apparent: firstly, the major elements of IPM operating the stabilising mechanisms on the pest. Secondly, the components of IPM which constitute the array of control tactics that can be integrated in a harmonious manner to regulate the pests.

In considering the major elements of IPM, we focus attention more on the ecological boundaries of the agricultural estate and the factors operating on the pests and the crops which constitute in effect the agro-ecosystem. According to Smith (1962) this includes the total complex of organisms that is, the pest species, their natural enemies, competitors, associates, their food together with the host plant, associated weeds and other plants; the soil and its management, the overall conditioning physical environment and in most cases the various agricultural, industrial, social activities of man, all constituting the unit.

The elements of IPM precedes any strategy for IPM control in that it is based on the proper assessment of these major elements that one can decide on which appropriate strategies of control to adopt. Accordingly, the proper and orderly development of an IPM requires a good scientific background and the development of certain information base as discussed extensively by Beingolea *et al.* (1983).

Under the major components of IPM, cultural control (as reviewed by Lawani, 1982), host plant resistance, chemical control (Knipling, 1979), biological control (Huffaker, 1980) and other components like physical and mechanical control, regulatory control, autocidal control including genetic manipulation of pests and many other innovative practices as discussed by Metcalf and Luckmann (1982) constitute the array of control tactics that can be integrated in a harmonious manner from which the IPM strategy is developed. The above explanation on IPM concept then constitutes the information recall needed to determine the knowledge base or awareness and understanding of such a concept.

KNOWLEDGE DOMAINS

Knowledge within our context refers to the information a person has about an object. It refers to the information base that enables people to be aware of, comprehend and understand objects, events and actions. Knowing and understanding an object enables one to describe its characteristics and link it to other attributes. Knowledge can manifest itself through two types of reality — experiential reality and agreement reality. Experiential reality are those things that one knows as a result of previous experience. On the other hand, if one learns from others what they agree to be real, then the process of learning is through agreement reality. The above explanations indicate that we build our knowledge based on our experience or the experiences of others. In real life, we build our knowledge through a prolonged learning process (formal or informal) since childhood and through our experience as we grow.

Knowledge alone does not determine whether the person will behave according to what he knows. How a person behaves or what he does is also determined by another construct: his attitude. Attitude constitutes the affective structure of a person, that is, how he feels towards what he knows. If his attitude is positive towards a certain knowledge, he will behave according to the knowledge he received. Very rarely does a person behave contrary to his attitude and knowledge. If that happens, then we are dealing with a realm known as cognitive dissonance. Knowledge base of a community can therefore be measured. This is usually accomplished through surveys.

COMMUNITY PERCEPTION OF KNOWLEDGE

Measuring the knowledge, attitude and practices (KAP) of people through KAP surveys pre-supposes that differences actually exist between what a person knows, how he feels and what he does. As often pointed out by social psychologists, knowledge has only the cue value while attitude has both cue and drive (motivation). This can be interpreted further to mean knowledge exerts a directive influence while attitude exerts both directive and dynamic influence on behaviour.

These interpretations can best mean that in most baseline surveys, we are interested in not only what a person knows but whether he understands what he knows as well. In a needs assessment survey such as KAP survey we are interested in not only knowing for example, whether what the farmer knows about an object is important (awareness) but why (comprehension) is important as well. The rationale for this linkage is because of the conceptual agreement that if a person fully understands what he knows, the knowledge will be retained longer than the knowledge obtained without understanding.

This linkage becomes crucial in finding answers to why innovative agricultural technologies as mentioned earlier seem not to be highly adopted in the African agricultural setting. Is it because the community-based knowledge of the technology in itself is suspect? If so, will that not induce a negative attitudinal factor on the target's behavioural responses?

MOBILISING COMMUNITY KNOWLEDGE BASE IN DEVELOPING IPM

As much as we recognise the merit of IPM in pest controls, we have to fully recognise that factors that led to the need for IPM under advanced western type high energy input agriculture are not the same as the same critical issues in most tropical agricultural systems in Africa (Amoako-Atta, 1987). Whereas overreliance on chemical pesticides created the awareness and the urgent need for an ecologically sound approach to pest management within advanced energy input agriculture (FAO, 1966) very insignificant proportion of pesticides are used by the critical mass of farmers in most of the small-scale farmers fields in Africa. Unlike in the United States of America for example, where according to Bottrell (1979) crops accounted for an estimated 95% of the pesticides used in the USA agriculture, poverty, lack of financial resources to procure chemical pesticides, scarcity of the pesticides, and general ignorance on the correct use of these chemical pesticides have contributed greatly to the insignificant use of these pesticides by most African farmers. At present there is hardly any significant use of herbicides by these farmers, and weeding is still manually done in most cases. This is a situation where generalisation can be made that most African farmers' level of awareness of pesticides may be high, yet their comprehension of proper use of pesticides may be a limiting factor. In other words, the wary and very conservative African farmers always tend to be slow to venture into the unknown, where they do not have adequate understanding about a product, or recognise their inability to use certain things, they tend to shy away from such products. Such behaviour becomes accentuated especially when such involvement entails an element of cost or financial obligation. As such most farmers in Africa still resort to the "no action" approach (Barfield and Stimac, 1980) when faced with pest problems or in most cases they resort to cultural practices like intercropping, bush burning, no tillage among others, as preventive cultural control practices.

This virtual absence of pesticides use in most small-scale agriculture in Africa should influence our thinking into a new premise that should become the motivating factor in focusing on IPM as an innovative technology for the benefit of the African farmer.

Most probably, the effective deployment of factors of production to increase productivity or bridge the existing productivity gaps between the traditional farmer and high energy input advanced agricultural systems should thus become our focus or the premise of concern.

Existing productivity gaps in most of these traditional farming systems have been recognised and reported elsewhere (Johnson and Clark, 1982). An attempt at conceptualising the effects factors of production have on productivity within two contrasting farming systems using a peasant type upland rice farming system will be used as a basis to establish the premise of concern in developing the IPM for the target African farmer.

PREMISE OF CONCERN FOR COMMUNITY INVOLVEMENT IN IPM DEVELOPMENT

The first such scenario is that of a traditional upland rice farming system under which farmers resort only to manual labour, traditional cultivation practices like broadcasting of rice seeds, mixed cropping, use of cutlass and hoes as the only input factors of production. The second scenario depicts the research station energy intensive upland rice cultivation as the other advanced or complex model.

A closer look at the projected outputs from the two scenarios are intended to offer some explanation on both the technical analysis of production and the socio-cultural and economic implications on the technical factors of production. Both of which will help in the prediction of community understanding and involvement in such production activities.

For our first consideration, if we were to evaluate a single input factor of production such as seed type on yield, the relationship might be described for the upland rice as follows:

$$Ry = Rm\ (U) \quad \text{.......................} \quad (1)$$

Where

Ry = Rice
Rm = Minimum rice yield
U = Coefficient of yield increase with cultivation and seed type

A comprehensive and more complex relationship of rice yield under research station generated major input production is illustrated as follows:

$$Rya = Rm, (S, Do, F, St, Mo, P, Me, Mn, L, Tp, Th) \quad \text{.......................} \quad (2)$$

Where

Rya = Rice yield under research station managed upland rice cultivation estimated at about 1.5 tons per acre (WARDA, 1982)

Rm = Minimum rice yield.

S = Seed type or cultivar used.

Do = Planting density usually under monocroping and recommended plant spacings based on research station.

F = Fertiliser application (N, P, as needed).

St = Soil type (proper consideration on soil suitability for rice production).

M = Moisture (irrigation supplement to avoid moisture stress).

Me = Mechanisation (to facilitate timely land preparation, planting and other vital operations).

Mn = Management (effective supervision/utilisation of resources within the farm operation — controlled by high calibre research scientists).

L = Labour inputs — usually skilled labour for specific operations under effective management.

Tp = Time of planting (ecological considerations carefully evaluated through research to generate suitable planting dates).

Th = Time of harvesting (determined through research to minimise harvest related losses).

From model 2 above, it can be seen that, for the research station upland rice systems to generate the expected average yield of 1.5 tonnes/acre requires effective integration of the factors of production identified in model 2. These factors interact to give the projected response under high calibre research scientist managed operation.

Unlike the research station generated upland rice production system (model 2) which is a highly complex system, a model of upland rice traditional farming system (model 3) within which the farmer makes three basic decisions with conservative optimism and assurances by selecting his own planting materials, adopting very simple cultural practices by using the cutlass and hoe for all cultural operations with his household labour and, in exceptional cases with little or no fertility levels, and with or without the threat of pest attacks now follows:

$$Ryb = Rm\,(S, Dm, L, A, H) \quad \text{.............} (3)$$

Where

Ryb = Rice yield under traditional farmer upland rice cultivation in most West African countries estimated at around 500/acre (WARDA, 1982).

rM = Minimum rice yield.

S = Seed type or cultivar used — usually of unknown genetic history.

Dm = Plant density within subsistence agriculture usually part of a polycultured system with broadcasting of seeds as the preferred method of planting.

L = Labour — usually household labour.

A = Axe/Cutlass.

H = Hoe.

A careful look at models 2 and 3 above, clearly underscores the fact that model 2 which gives a higher productivity does so at extremely higher energy and other input costs. Model 3, although with low productivity is naturally occurring under very low production input factor situation. The traditional farmer recognises this inherent advantage in spite of the low productivity experienced.

The expressed productivity gap between the traditional farmer situation and the research station situation can thus be equated as in model 4 below:

$$PG = Rya - Ryb \qquad (4)$$

Where

PG = Productivity gap within the subsistence agriculture.

Rya = Rice yield under research station managed upland rice cultivation.

Rya = Rice yield under traditional farmer upland rice cultivation.

PG = Productivity gap within the subsistence agriculture.

Rya = Rice yield under research station managed upland rice cultivation.

Ryb = Rice yield under traditional farmer upland rice cultivation.

The intensity of productivity gaps can be determined for different situations by conceptualising the factors of production for each situation, as has been analysed above. This analysis clearly illustrates in part, why results from research stations in most parts of African countries are not easily realised under farmer situations. The basic question then is, what production factors need be added to model 3 or improved upon, to effect productivity increase?

These questions arising from the foregoing analysis should constitute the "premise of concern" for any IPM interventions in subsistence or small scale tropical agriculture.

We all recognise that by controlling pests, we attempt to prevent losses that otherwise would affect our potential outputs. However, pest control does not generate or increase production levels but only consolidates potential production based on existing inputs of production and management capacity operating on the system. If the prevailing inputs of production and management capacity are poor and/or inefficient (ref. model 3 above), then efforts at increased production should be based on the improvement of the factors of production. For example, if by using an improved resistant cultivar, by adopting a newly developed pest management strategy, or by selecting good planting sites without any drastic changes on the management capacity of the farmer or his production input factors confronting him could induce significant increase in production response at current subsistence levels, then the new input factor combination for such modified traditional farming system could be represented as model 5 below:

$$Ryc = Rm\,(SI, DmI, L, A, H, P) \quad \text{.......... (5)}$$

Where

Ryc = Rice yields under improved traditional farming system.

Rm = Minimum rice yield.

SI = Improved resistant rice cultivar.

DmI = Improved planting density — e.g. planting in rows instead of broadcasting.

L = Labour — still depending on household labour.

A = Axe/cutlass.

H = Hoe.

P = Pest control interventions.

It is only based on such manipulation of factors of production to improve productivity can a carefully designed IPM strategy be of relevance to the traditional farmer.

It must be stressed, however, that an increase of farmer production levels from about 500 lbs/acre as in model 3 to about 800 – 1000 lbs/acre as in model 5 may not look attractive or comparable with Western type advanced agriculture, but this must be viewed within the context of "relevance" and easy adoption by majority of farmers without overburdening their management and economic capacity. The projected level of increase could even be higher under careful experimental modifications. This is even more crucial when we realise that neglect of research and a consequent lack of feasible and profitable technologies suited to a variety of local conditions appear to be particularly serious in sub-Saharan Africa.

This logic must be viewed also, under the context of prevailing farming systems where farmers are constrained by many endogenous and exogenous factors to limited farm sizes of under one acre to sizes of less than five acres, and have persistently been unable to take advantage of high input agricultural systems (model 2) for obvious reasons. Thus, do we therefore have to still pursue research goals that advertise goals of high productivity (model 2) within high input economic activities which the average traditional farmer who is chronically saddled with socio-economic constraints (model 3) finds it difficult to easily accept and adopt? Or, should we focus attention on goals that can be attained at lower production, but requires concerted and sustained adaptive research support as in model 5 or something even better where the whole farmer situation is being carefully assessed in a holistic and more realistic manner?

MOTIVATING THE COMMUNITY FOR ACTION IN DEVELOPING IPM

To motivate a community into participatory action towards the development of IPM requires a shift in our strategy in dealing with the critical mass of our target farming community. In our case, for tropical traditional farmers, the required strategy should be one of going for the quickest gains first: that is focusing on those actions that produce the biggest impact for the least cost. The very low starting point of small holder agriculture makes it perhaps the most promising area for action. Because yields are so low and inputs so minimal, gains from modest investments can be very dramatic, with yield increases of 15 per cent upwards and financial gains of 40 per cent or more.

As we have seen from the above scenarios, (and equally applicable to most African countries), until recently most West African governments neglected small farmers in favour of the urban sector. This implied that if cities and industries were to develop, the resources had to be taken from the rural and farming sector, by way of taxes and low procurement prices for food and cash crops. By pegging food prices low in itself, served as disincentive for farmers to embark on capital intensive high energy demanding form of agricultural activity (like scenario 2). The strategy produced nothing but low output, dependence, mass poverty and tiny, stagnant home markets for industry. Everyone lost out, resulting in mass exodus of middle level skilled manpower—synonymous to brain drain.

In a continent where seven out of ten people are farmers and their families, healthy growth is possible only where agriculture prospers. If agriculture is fostered, rather than exploited or misdirected, the situation can shift into positive growth, one in which everyone gains. With higher producer prices, farmers have an incentive not only to grow more but to embark on factors of production that foster higher productivity.

Small farmers must be the focus in our consideration of the African community. They constitute the overwhelming majority of farmers in all African countries, and because land is still fairly equally distributed, they account for most of the farmed areas. They also make up the majority of the population, and the majority of the absolutely poor and malnourished. Hence in Africa, helping the small farmer creates four basic advantages in national development. That is, firstly the best way of boosting national self-sufficiency in food; secondly provides the dependable way of improving incomes of the majority; thirdly, thereby reducing mass poverty and malnutrition; and lastly serves as the effective way of conserving the environment of which the African peasant is, no matter how we look at, the effective custodian.

To realise this shift, there should be concurrent redirection of the technology transfer process. Technology development and transfer must be properly structured and planned to ensure relevance of the technology being developed and high efficiency in the adoption process of the technology by the target group.

Due to the incorrect but widely held perception, especially among agricultural scientists or subject matter specialists, that the primary function of extension is to "disseminate" agricultural technology packages generated by research stations to farmers. There appears to be a heavy "technology-bias" orientation (ref. model 2 above) in many extension programmes. There have not been adequate considerations given to the human behavioural aspects, such as the socio-psychological, socio-cultural and socio-economic factors which may facilitate or impede adoption, or continued practices of recommended technologies by farmers. Without sufficient understanding of their positive and/or negative attitudes and behaviour towards a given technology, the process of technology transfer would be slow and ineffective, especially if the emphasis is on appropriate technology by farmers.

A strategic extension campaign (SEC) methodology (Adhikarya and Posamentier, 1987) developed by FAO which takes into consideration such issues has been introduced in many Asian countries, and to a limited extent to some African countries. This methodology emphasises the practical application of strategic planning and systematic approach to agricultural extension and training. It has a problem-solving orientation. Thus, its extension strategies and tailored messages are specifically developed on the basis of participatory problem identification process on the causes or reasons of farmers' non-adoption or inappropriate practices regarding a given recommended agricultural technology or innovation. The SEC method includes a farmers' Knowledge, Attitude and Practice (KAP) survey whose results are used as campaign planning inputs and bench mark/baseline for summative/impact evaluation purposes.

A weakness of many agricultural extension services is the lack of systematic and strategic planning in terms of problems identification, objective formulation, programme development and information/message positioning as well as in the cost effective use of extension resources (including extension workers, multi-media channels, and/or materials etc). In many cases, extension programmes are sporadic and carried out on *ad-hoc* basis because they have not been planned in accordance with a given explicit policy and/or strategy. Here, we have to be mindful of the fact that technology once developed, if inappropriately transferred, or if never efficiently adopted, is tantamount to wastage of valuable resources. To avoid such a problem, SEC advocates an integrated and holistic approach in strategy development, programme planning and management, training, media and/or materials development and monitoring and evaluation. To ensure its programme relevance to audience needs, and to utilise its resources efficiently, SEC relies heavily on both quantitative data and qualitative information to assist in problem analysis, objective formulation, strategy development and implementing planning. It thus applies a strategic planning approach in programming and managing its activities, to achieve maximum outputs or results using minimal inputs or resources in the shortest time possible.

SEC is responsive to the target audience's agricultural development problems and information needs because its extension programme objectives, strategies, methods, messages and multimedia materials are specifically developed based on survey results of the target group's knowledge, attitude and practice (KAP) vis-a-vis the recommended agricultural technology (ies). Such a participatory approach in planning strategic extension campaign programmes increases the degree of relevance, and their acceptability of extension messages or recommendations among other target audience who had been committed during the planning process regarding their priority concerns and needs. It does not assume the target audience (i.e. farmers) of being ignorant or requiring all the information (as produced by the research station) there is to know. Rather it tries to understand and assess farmer's local indigenous knowledge, values and belief system on farming practices which may be good, need to be improved or perhaps need to be discouraged. Stated in another way, this SEC follows the well-known principles of rural reconstruction: start with what people already know (e.g. in Model 3), and build on what they already have (e.g. in Model 5).

From this analysis, it becomes apparent that both technology development and its transfer require a multi-disciplinary and team-work approach among researchers, subject matter specialists, extension officers, trainers, and communication support staff in its planning, training, implementation and management aspects. In many extension programmes, the lack of close collaboration and coordination among these workers, especially in field implementation, has been identified as one of the problems of agricultural development, especially in tropical Africa. Frequently, extension officers are not involved in the planning phase or process of a given agricultural development programme. Recommended technologies, especially in complex areas like Integrated Pest Management, generated by researchers and subject matter specialists could be made much more relevant to farmer's needs if extension workers, trainers, communication support staff and also farmer's representatives are actively involved in planning the research agenda and priorities, as well as in developing cost effective strategies for informing, motivating and educating farmers to adopt and appropriately practice such technologies.

CONCLUSION

In conclusion therefore, the basic consideration for developing an integrated pest management for our critical mass of farmers is to have the technology benefitting and reaching a large number of our small scale farmers. This requires a strategically planned and problem-solving oriented extension programme conducted in a relatively short time period, aimed at increasing awareness/knowledge level of an identified target audience and altering their attitudes and/or behaviour towards favourable adoption of the given idea or technology, using specifically designed messages and cost-effective multi-media materials to support its information education/training, and communication intervention activities. This can best be accomplished by incorporating the FAO strategic extension campaigns (SEC) strategy into the evolving research station technology development process.

If the IPM development process is to ever reach and benefit the target group as defined then this strategic planning becomes imperative. For, one of the most common problems or constraints of a national extension service (which is always expected to promote any innovative technology from other national or international research centre) is the shortage of field extension personnel to reach the large number of farmers in widely spread geographical areas with inadequate transportation facilities.

Moreover, the extension workers are usually over burdened with their unnecessarily heavy work-load which includes almost everything that has to do with farmers at the village level. Such an over reliance on extension workers is neither technically sound nor operationally efficient. Some extension functions for certain purposes such as awareness creation, information delivery, motivational campaigns etc. can be more effectively and efficiently performed by other means, channels, or non-extension groups under the coordination and supervision of extension workers.

Extension workers' work-load could be reduced by mobilising appropriate rural and community-based resources including the increasingly accessible and low cost mass communication channels (i.e. local radio stations, rural press, folk/traditional media, posters, flip-charts, slide-tapes presentations, leaflets, comics, etc) to disseminate standardised and packaged extension messages, as well as in utilising local volunteers such as school teachers and children, local/religious leaders, to serve as intermediaries in reaching farmers. Such an approach does not imply that extension workers can or will be substituted by the community resources. Rather it is a rational approach of using available resources most effectively and efficiently for certain tasks, such as the need to use extension workers for educational or instructional purposes which requires two-way interaction, field demonstration, group discussion, etc. which can be done as effectively by mass communication channels. But, all said, the technology development process has to be integrated with the technology transfer process right from the technology identification and development phases through a participatory multi-disciplinary team approach which recognises the element of both technical and human dimensions of the problem that necessitates the technology development process. More importantly, if the technology, as is the case for an IPM, is intended to benefit the small scale African farmer, the technology development process must be so designed and structured to complement and improve the programmes of a national agricultural extension service. This can be realised if strategic programme planning and strategic extension planning approach are incorporated in the projected technology development and technology transfer processes.

REFERENCES

Adhikarya, R. and H. Posamentier (1987). Motivating farmers for action. How strategic multi-media campaigns can help. *Schriftenreihe der GTZ*, No. 185 Eschborn.

Amoako-Atta, B. (1987). Subsistence agriculture in Africa: Problems and Prospects. *ABN/UNESCO publ.* Dakar-Senegal. 271 pp.

Barfield, C. S. and J. L. Stimac (1980). Pest management: An entomological perspective. *Bioscience* 30, 683–689.

Beingolea, O., R. E. Frisbie, L. A. Falesn, R. F. Smith, L. J. Mathews, R. Daxl, I. Tolis, L. T. Wilson, A. F. Hearn, P. M. Ives, N. J. Thomson, E. S. Tsi and H. L. Lin. (1983). *Guidelines for Integrated Control of Cotton Pests.* FAO, Rome.

Bottrell, D. G. (1979). *Integrated Pest Management*, US.

FAO (1966). Report of the 1st Session of the FAO Panel of Experts on Integrated Pest Control. FAO, Rome.

FAO (1984). *World Food Report*, FAO, Rome.

Huffaker, C. B. (1980). *New Technology of Pest Control.* John Wiley and Sons, New York.

Johnston, B. F. and W. C. Clark (1982). *Redesigning Rural Development. A Strategic Perspective.* Johns Hopkins University Press, 311 pp.

Knipling, E. F. (1979). Basic principles of insect population suppression. *USDA Handbook* No 512. Washington DC, 659 pp.

Lawani, S. M. (1982). A review of the effects of various agronomic practices on cereal stem borer populations. *Trop. Pest Manage.* 28, 266–277.

Metcalf, R. L. and W. H. Luckmann (1982). *Introduction to Insect Pest Management.* Wiley Interscience, New York.

Murphy, T. P. (1956). *A Business of Your Own, How to Select, Finance and Start it Successfully.* McGraw-Hill, New York. p. 4.

Smith, R. F. (1962). Principles of Integrated Pest Control. Paper given at North Central States Branch of ESA — March 21, 1962.

Biological Control and the Rural Community

D. Moore

International Institute of Biological Control
Silwood Park, Buckhurst Road,
Ascot, Berkshire, SL5 7TA UK

SUMMARY

Pest infestations are usually considered to be a problem primarily for the farming community, but pests and their control often have a direct effect on the whole community. Examples are given of two introduced pests and the social implications of their infestations and of attempts at their control by introducing exotic natural enemies. Classical biological control (by introduction) has the most far reaching consequences and yet is least controlled by local communities. Other biocontrol techniques, such as augmentation and conservation, can be directly performed by the farming community and are usually reversible. With some pests the general community may have to participate and provide labour or a financial input to compensate farmers for their control work.

INTRODUÇTION

Developments in early crop based agriculture have sometimes been considered to have been largely empirical, and scientific farming has developed only over the past few centuries. However communities developing settled agriculture, and others such as hunter-gatherer and nomadic groups, by necessity exhibit great knowledge of their environments. Agriculture requires farmers to have systematic and formulated knowledge and consequently the fundamentals of agriculture have been subjected to practical scientific experimentation for many centuries.

Farmers are interested in reliable crop yields under the, perhaps very variable, climatic conditions prevailing, and may not know why certain actions gave certain results. They developed techniques that gave the required results, and often these techniques had crop protection aspects. Cook (1986) describes some of these: crop rotation for example prevents the build-up of pathogens specialised for specific crops; tillage may expose pathogens to attack by microbiota and directly kill insect pests or expose them to predators (birds, insect predators, etc.); adding organic materials including ash can promote plant health, often increasing resistance of the plant to pests and increasing biological activity against pathogens by soil microbiota (also see Hornby, 1990). Farmers also carried out plant breeding and developed biological and cultural methods of pest control and the use of insecticidal plants (Stoll, 1988; Jacobson, 1990; Konishi and Itô, 1973).

Development of agriculture was slow and dependent on sustainability; over the last century developments have been rapid and, in some cases, reliant on expensive inputs. Increasing use of inorganic fertilisers, new cultivars and chemical pesticides has occurred largely at the same time that scientists have become more specialised and separate from the farming community. This specialisation has enabled very rapid scientific advances, and the adoption of new techniques has shown the adaptability of farmers. This separation has implications in all aspects of agriculture, including that of crop protection by biological control. The scientist has to develop practical control techniques, often by adapting pre-existing ones, which are practical for farmers to use.

BIOLOGICAL CONTROL

In the present context, the term biological control will be restricted to the various uses of living natural agents to suppress pest organisms and manipulation of the environment to enhance the effect of pre-existing or introduced natural agents. The main techniques used are introduction of natural enemies (classical biological control), inoculation, augmentation and inundation (sometimes all grouped under augmentation) and conservation. Other biological methods of control such as crop rotation, manuring, resistant cultivars, etc., are not included despite their obvious crop protection value and reference is made to them only if they directly influence numbers, or actions, of natural agents.

Depending upon the biocontrol techniques used there may be great or little interaction between scientist and farmer. With biological control, the interest of the scientist is usually clear. This is control of the target organism in an economic way using effective, safe agents. However, for the communities receiving the biological control there may be many interests, some conflicting. Two recent classical biological control programmes will be briefly described to illustrate this.

RASTROCOCCUS INVADENS IN WEST AFRICA

This mealybug became a serious pest, especially of mango and citrus, in West Africa from the early 1980s. Explorations in India resulted in a suitable parasitoid being tested under quarantine at IIBC, UK, before being transported to Togo. Early results suggest an extremely good level of control (Agricola *et al.*, 1989). There was wide ranging research involving eleven scientists working in the UK and four in India and Malaysia. These included taxonomists, exploratory scientists and researchers doing detailed laboratory studies; only one of these was involved in work in the biocontrol programme in West Africa. Establishment of the parasitoid in Togo was accomplished by Togolese and German scientists and further work in West Africa has been coordinated by the International Institute of Tropical Agriculture in Cotonou, Benin.

A preliminary sociological and economic evaluation was given by Vogele *et al.* (in press). Economically the benefits of control exceeded the programme costs by a wide margin. However, because the pest reduced crop yield, reduced the vigour and shading abilities of the trees, and attracted troublesome insects, this affected community life in many ways. The preservation of mango and citrus was important because:

(a) *Nutritional.* Mango and citrus provide energy and vitamins in areas of low nutritional supply.

(b) *Medical.* Traditional preparations of mango leaves are used medicinally.

(c) *Communal events.* Formal and informal meetings, social and educational events take place under trees.

(d) *Spiritual.* Prayer meetings may be held under trees and animist worshippers believe that gods are incarnate in trees. Trees planted by forebears are emotionally important to a family. The presence of the predatory lepidopteran *Spalgis* sp whose pupa is patterned like a human face, is a sign of bad luck.

(e) *Aesthetic.* Many ornamental plants and shade trees were disfigured by infestation.

(f) *Harmful control measures.* Chopping down of trees and use of pesticides were environmentally harmful.

This range of problems, created by the infestation, ensured that control was welcomed by the whole community. In Togo, extension leaflets were produced, radio and television broadcasts made and a release ceremony was performed at one site. This publicity was necessary as the farming community had no involvement in the programme, apart from seeing the benefits of the control.

GORSE (*ULEX EUROPAEUS*) IN NEW ZEALAND

Gorse, a spiny shrub which can form impenetrable masses over 2 m tall, is considered by farmers to be one of the worst introduced weeds in New Zealand.

Tetranychus lintearius (Acari, Tetranychidea) has been introduced for control but the project is at too early a stage for the results to be predicted. However gorse has some beneficial characteristics (Hill, 1989):

(a) It provides a valuable source of pollen to feed honey bees in early spring. Shortage of pollen leads to fewer worker bees and reduced honey yield.

(b) Gorse may be a valuable nurse crop for regenerating natural forest trees.

(c) May be a fodder crop for goats.

(d) Grows and stabilises slopes susceptible to soil erosion.

(e) Gorse is used as a hedge plant.

Thus, in contrast to the case of *R. invadens* there were members of the community who opposed control of gorse.

These conflicts of interest mean that despite the work of the scientist having specific biological aims, the results may also have important and varied social impact. Similar examples could be produced for projects in which the target organism is controlled by biological control techniques other than introduction. These may be with either the farming or the wider community. Classical biological control is often implemented without the direct involvement of the community and yet this technique has the most widespread and long lasting effect. Other biocontrol techniques can demand a large input from farmers, sometimes financial, but often in terms of labour. This gives a great degree of control to the community as farmers can make decisions on a seasonal basis.

INTRODUCTION — CLASSICAL BIOLOGICAL CONTROL

Classical biological control is the permanent establishment of imported natural enemies to give self perpetuating long term control. With many examples of introduction, farmer involvement may be nil, but sometimes the introduced agents may need assisting for full efficacy.

The coffee berry borer, *Hypothenemus hampei*, is a serious pest in most coffee producing countries. Two bethylid parasitoids, *Cephalonomia stephanoderis* and *Prorops nasuta*, have now been transported to a number of countries. Mass rearing is possible to enable establishment of the parasitoids in a number of areas, but they colonise new areas only very slowly and their populations are reduced when the berries are harvested at the end of the season. Farmer involvement could include moving berries containing parasitoids to coffee areas without the parasitoids, then rearing the parasitoid after final harvesting for release into the field at the beginning of the next season (augmentation), or adapting the agronomy of the crop. For example, interplanting cultivars with different phenologies could ensure a continuous supply of hosts for the parasitoid, and altering shading causes changes in the levels of parasitism (conservation) (Murphy and Moore, 1990).

INOCULATION AND AUGMENTATION

Inoculation is the periodic, usually seasonal, release of natural enemies unable to survive permanently, while augmentation is the periodic release of natural enemies already present to boost their impact on the pest.

These can be considered together in terms of practical activity. Both involve production and release of natural enemies and can involve a heavy commitment by the farmer. The inoculation technique would almost invariably involve the introduction of an exotic to the area, while augmentation could be to supplement either an introduced or a native species. Examples of augmentation in the People's Republic of China are given by Cock (1985).

For example, the litchi stink bug, *Tessaratoma papillosa* (Pentatomidae), is attacked by the native egg parasitoid *Anastatus* sp (Eupelmidae). Towards the end of the season parasitised eggs are collected and the emerging parasitoids used to attack *T. papillosa* eggs in rearing boxes. The resultant parasitised eggs can be stored for up to 6 months at 10–12°C and then put out into each tree the following spring.

The whole process could be accomplished by the farmer (with access to cooled storage conditions), or some or all the stages accomplished by a commune, cooperative, small local businesses, etc.

At the very least, farmers are likely to be involved in distributing the agents; in many glasshouse systems in temperate climatic conditions small producers supply packets of natural agents (parasitised eggs, predatory mites, etc.) for the growers to place on their crops.

INUNDATION

Inundation is the mass release of natural enemies to act as biological pesticide for short term pest control.

Notable examples are the use of *Trichogramma* spp in areas as diverse as Nicaragua, the Philippines, Western Europe, China, etc. In China pest problems in up to 1 million hectares have been managed using *Trichogramma* spp (Cock, 1985). Rearing is normally in production units and research is necessary to refine rearing techniques. Usually production of parasitised eggs on cards is achieved at a central point and distribution in the field done by the farmers. Sometimes the *Trichogramma* spp. establish and the system has then become an introduction, often supplemented by augmentation (Felkl, 1989).

The production and use of pathogens may be an area where farmers could be increasingly directly involved. Jones (1988) gave examples of the use of baculoviruses as biopesticides; in Thailand nuclear polyhedrosis viruses (NPVs) are being assessed on the noctuids *Heliothis* sp attacking cotton and *Spodoptera exigua* on onions. In the case of *Spodoptera* NPV the Ministry of Agriculture supplies an inoculum of virus with instructions on how to produce the virus using field collected *Spodoptera*, how to store, prepare and to spray the inoculum.

Farmers also produce the NPV virus used to control the velvet bean caterpillar *Anticarcia gemmatalis* on soya bean in Brazil.

NPV virus is also used against *Spodoptera littoralis* on cotton in Egypt, and the programme is developing practical methods of production and formulation suitable for local farmer use.

Production of *Bacillus thuringiensis* is usually from refined systems, although application is done by the farmer. Mass production of *Bacillus penetrans*, for control of root-knot nematodes (Stirling and Wachtel, 1980) may be feasible for small-scale production by farmers. Commercial preparations of *Agrobacterium radiobacter* can be used to control crown gall caused by *Agrobacterium tumefaciens* (Ryder and Jones, 1990).

Two fungi used to control major pest problems are *Metarhizium anisopliae* and *Beauveria bassiana*. In Brazil private business produce *M. anisopliae* in simple laboratories for farmers to use against *Mahanarva posticata* (Homoptera: Cercopidae). Production of *B. bassiana* in China for use against *Ostrinia nubilalis* is simpler, but in both cases raw materials and equipment are simple, cheap and locally available (Prior, 1989). There has also been great interest in control of *Hypothenemus hampei* in Latin America using locally produced *B. bassiana* (Murphy and Moore, 1990).

Parasitic fungi for use against nematode pests can also be mass produced (Lohmann and Sikora, 1989) and could be used in simple integrated management systems (Zaki and Bhatti ,1990).

These biological pesticides can be produced by farmers individually or in small communities, as well as commercially. Advantages of a local production are that it is cheap, can use agricultural waste products (Awuah, 1989), and the low technology systems may be no more difficult than other traditional fermentation processes used in many parts of the world (Prior, 1989). Application involves farmers using the same machinery as for chemical pesticides, with which they are familiar.

Inputs from scientists are still necessary to develop the most suitable formulations. IIBC has a project for biocontrol of locusts and grasshoppers using fungal pathogens such as *Metarhizium* spp and *Beauveria bassiana* as biological pesticides. Scientists are exploring for pathogens in Pakistan, Oman and West Africa and existing culture collections are being investigated for isolates that may be bioassayed to determine which are potentially the most suitable. Work is being conducted on storage of the pathogen, UV protection, formulation to allow ULV application with hand held or machine operated sprayers and mass production systems. This should allow a stable commercial product to be developed which could be sold to farmers like any other pesticides, or help in the development of a locally produced biopesticide.

CONSERVATION

Conservation is the modification of the habitat or cultural practices to enhance natural action. Habitat diversity can be increased by providing alternative hosts for times when the pest host is rare, and by providing adult food sources and shelters (Powell, 1986). Techniques such as intercropping or mixed cropping, strip harvesting, planting of windbreaks, using resistant or tolerant cultivars, timing of agricultural practices (Powell, 1986 and references therein) can also be used to increase parasitoid and predator activity.

Agronomic techniques such as crop rotation, fertilising, method of tillage (e.g., direct drilling versus ploughing) can influence the biological control of pathogens and insect pests (Cook, 1986; Moore *et al.*, 1986). The addition of organic matter such as cattle manure (Adesiyan and Adeniji, 1976), green leaf or crop residues (Luc *et al.*, 1990) stimulates the levels of organisms that control plant parasitic nematodes (Mankau, 1962), although some of the effect may be due to nematicidal components produced by decomposing plant residues (Sare *et al.*, 1965).

Conservation brings responsibility largely back to the farmer for ecologically sensitive pest control, but science can exploit the mechanisms by which conservation techniques limit pest numbers. The synthesis of allelochemicals to deter pests or to attract natural enemies, breeding of plants to produce these allelochemicals or otherwise to improve the performance of entomophagous insects (Nordlund *et al.*, 1988), and synthesis of the sex pheromone of the pest to attract its parasitoids (Powell, 1986) are a few examples of input by scientists that may have practical benefits. However, practising farmers, using their experience and knowledge, are always carrying out practical experimentation on many agricultural systems while researchers can only work in much more restricted fields.

DISCUSSION

The often separate activities of the agricultural research scientists and farmer may appear unfortunate; applied research should be relevant to farmers' needs. However, in some biocontrol projects only a little research worker/ farmer interaction may be necessary. In many classical biological control programmes most work, for example exploration in the areas of origin of the pest or studying the biology of the pest and natural agent, will be done far away from the problem. Farmers do need to be aware of introductions so that they use suitable agricultural techniques (e.g. avoiding pesticides use). Involvement of farmers with other techniques is much greater and, especially with conservation, farmers should be the major innovators. Scientific advances will be adopted by farmers if they demonstrably work, as evidenced by the rapid uptake of the use of, and technology required for, chemical pesticides.

Farmers will only do the biological control that directly benefits them. With polyphagous pests, especially those which attack non crop plants as well as crops, such as *R. invadens*, techniques other than introduction, even if effective, would only be carried out on crops or domestic plants. If control were to be carried out for the benefit of the wider community, farmers would require incentives or the community would have to be prepared to pay the cost or provide the labour input for control.

Similarly, the use of biological pesticides against highly mobile pests such as grasshoppers or locust will require cooperative action from farmers. It can be several days before a pest is disabled by a biological pesticide, by which time the pest may have moved on and the effect of the pesticide is not seen by the individual who used it. Only by ensuring that all the local farmers are treating such pests will control be worthwhile for the individual farmers.

REFERENCES

Adesiyan, S. O. and M. O. Adeniji (1976). Studies on some aspects of yam nematode (*Scutellonema bradys*). *Ghana J. Agric. Sci.* 9, 131–136.

Agricola, U., D. Agounke, H. U. Fischer and D. Moore (1989). The control of *Rastrococcus invadens* Williams (Hemiptera: Pseudococcidae) in Togo by the introduction of *Gyranusoidea tebygi* Noyes (Hymenoptera: Encyrtidae). *Bull. Entomol. Res.* 79, 671–678.

Awuah, R. T. (1989). Preparation and evaluation of dehydrated mycological media from West African raw materials. *Ann. Appl. Biol.* 115, 51–55.

Cock, M. J. W. (1985). The use of parasitoids for augmentative biological control of pests in the People's Republic of China. *Biocontrol News and Info.* 6, 213–233.

Cook, R. J. (1986). Plant health and the sustainability of agriculture, with special reference to disease control by beneficial microorganisms. In *The Role of Microorganisms in a Sustainable Agriculture*, pp 125–146, (Eds. J. M. Lopez-Real and R. D. Hodges). A.B. Academic Publishers.

Felkl, G. (1989). Status of rearing, releasing and establishment of *Trichogramma evanescens* Westw. for control of Asian corn borer *Ostrinia furnacalis* Guenée in the Philippines. *Proceedings of the 1st DLG Conference on Integrated Pest Management in Tropical and Subtropical Cropping Systems.* Bad Dürkheim 8–15 February 1989, pp 625–633.

Hill, R. L. (1989). Environmental protection procedures and the biological control programme against gorse in New Zealand. *Proceedings of the VII International Symposium on Biological Control of Weeds.* Rome, 6–11 March 1988, pp 127–133, (Ed. E. S. Delfosse).

Hornby, D. (Ed.) (1990). *Biological Control of Soil-Borne Plant Pathogens.* CAB International, Wallingford, 479 pp.

Jacobson, M. (1990). *Glossary of Plant-Derived Insect Deterrents.* CRC Press Inc., Florida, 213 pp.

Jones, K. A. (1988). The use of insect viruses for pest control in developing countries. *Aspects of Applied Biology, Environmental Aspects of Applied Biology,* 17, 425–433.

Konishi, M. and Y. Ito (1973). Early entomology in East Asia. In *History of Entomology,* pp 1–20, (Eds. R. F. Smith, T. E. Mittler and C. N. Smith). Annual Reviews Inc., California.

Lohmann, U. and R. A. Sikora (1989). Mass production of the endoparasitic fungi *Drechmeria coniospora, Verticillium balanoides* and *Harposporium anguillulae* in liquid culture. *Nematologica* 35, 97–104.

Luc, M., R. A. Sikora, and J. Bridge (1990). *Plant Parasitic Nematodes in Subtropical and Tropical Agriculture*. CAB International, Wallingford, 629 pp.

Mankau, R. (1962). The effect of some organic additives upon a soil nematode population and associated natural enemies. *Nematologica* 7, 65–73.

Moore, D., R. O. Clements and M. S. Ridout (1986). Effects of pasture establishment and renovation techniques on the hymenopterous parasitoids of *Oscinella frit* L. and other stem boring diptera in ryegrass. *J. Appl. Ecol.* 23, 871–881.

Murphy, S. T. and D. Moore (1990). Biological control of the coffee berry borer, *Hypothenemus hampei* (Ferrari) (Coleoptera, Scolytidae): Previous programmes and possibilities for the future. *Biocontrol News and Info.* 11, 107–117.

Nordlund, D. A., W. J. Lewis and M. A. Altieri (1988). Influences of plant-produced allelochemicals on the host/prey selection behaviour of entomophagous insects. In *Novel Aspects of Insect-Plant Interactions*, pp 65–90, (Eds. P. Barbosa and D. K. Letourneau), John Wiley and Sons, New York.

Powell, W. (1986). Enhancing parasitoid activity in crops. In *Insect Parasitoids*, pp 319–340, (Eds. J. K. Waage and D. J. Greathead). 13th Symposium of the Royal Entomological Society of London Public. Academic Press, London.

Prior, C. (1989). Biological pesticides for low external-input agriculture. *Biocontrol News and Info.* 10, 17–22.

Ryder, M. H. and D. H. Jones (1990). Biological control of crown gall. In *Biological Control of Soil-Borne Plant Pathogens*, pp 45–63, (Ed. Hornby, D.). CAB International, Wallingford.

Sayre, R. M., A. A. Patrick, and H. J. Thorpe (1965). Identification of a selective nematicidal component in extracts of plant residues decomposing in soil. *Nematologica* 11, 263–268.

Stirling, G. R. and M. F. Wachtel, 1980. Mass production of *Bacillus penetrans* for the biological control of root-knot nematodes. *Nematologica* 26, 308–312.

Stoll, G. (1988). *Natural Crop Protection in the Tropics*. Margref Scientific Books, Weikersheim, Germany, 188 pp.

Vögele, J. M., D. Agounke, and D. Moore, (in press). Biological control of the fruit tree mealybug *Rastrococcus invadens* Williams in Togo: a preliminary sociological and economic evaluation. *Trop. Pest Manage.*

Zaki, F. A. and D. S. Bhatti (1990). Effect of castor (*Ricinus communis*) and the biocontrol fungus *Paecilomyces lilacinus* on *Meloidogyne javanica*. *Nematologica* 36, 114–122.

Development of Human Resources for Pest Management in the Tropics

Z. T. Dabrowski

The International Centre of Insect Physiology and Ecology (ICIPE)
P. O. Box 30772, Nairobi, Kenya

SUMMARY

ICIPE's training and education philosophy is based on the premise that, ultimately, Africans themselves must provide the solutions to the challenges of economic development, and specifically to problems posed by insect pests and human and livestock disease vectors. It is for this reason that since 1970, ICIPE is on the frontline in the development of capabilities in insect science leadership and practise. The training and education programmes at ICIPE are tailored to suit the needs of National Agricultural Research and Extension Systems (NAR & ES), universities and resource-poor rural communities. Current education and training thrusts include: (i) higher degree (leadership) training; (ii) non-degree training; (iii) professional development scheme; and (iv) interactive on-site (applied research training).

The African Regional Postgraduate Programme in Insect Science (ARPPIS) has registered 86 scholars for Ph.D. programme and 10 students for the M.Phil. programme in Biological Control from 18 countries. Ten scholars have been awarded M.Phil. and 25 Ph.D. degrees. All ARPPIS graduates are working in Africa.

Non-degree training is offered to insect science practitioners and frontline personnel within NAR & ES. Since 1977, 466 practitioners from Africa and the tropical developing countries participated in the group training courses. The courses organised between 1987–90 were mainly on integrated pest management technologies.

Under a Professional Development Scheme postdoctoral fellows, research associates, visiting senior scientists and professors come to the ICIPE to

develop and share expertise. To-date 94 scholars have benefitted from the scheme. Interactive on-site (Applied Research) Training embraces a joint work of ICIPE researchers and their counterparts within the NAR & ES on a specific insect pest or vector management problem.

INTRODUCTION

World Bank specialists in their recently published report on "Agriculture: The Primary Source of Growth and Food Security" stated that the task facing African Agriculture and Livestock production in the 1990s and beyond, is formidable indeed. It must cope with the needs of a rapidly growing population. It must achieve sufficient growth in food crops not merely to maintain output per person, but also to reduce food calorie deficits and to lower food imports. In the process it must be a major employer of Africa's growing labour force and compete on world markets to earn the foreign exchange that Africa needs to fuel its economic growth. And it must do all that while reversing the degradation of natural resources that threatens long-term production (Anonymous, 1989).

Better technology will be essential to achieve the targetted growth in output of 4 per cent a year over the medium and long term. The slow development of new agricultural technology in the past two decades reflects the decline in the quality of agricultural research in Africa. Weak government commitment and poor management rather than lack of money, have caused the current failure. Creation of human capital for science and technology in Africa is therefore now a priority of priorities for African agriculture. Technical assistance by itself in Africa has failed, over the last quarter century, to create the necessary condition for sustainable agriculture in Africa (Odhiambo, 1987). New technologies can only be developed through the building up of a scientific and technological capacity in the coming decade for four critical reasons:

(i) to create a knowledge-discovering capacity, particularly for the tropical environment in Africa;

(ii) to develop the ability to identify priority problems of national development requiring scientific and technological solutions;

(iii) to promote indigenous ability to choose between alternative technological pathways to the solution of these problems; and

(iv) to create the national expertise to implement the relevant solutions, whether the technologies are indigenous or modified from foreign technologies already in the market (Odhiambo, 1980).

All of these factors are also relevant to developing human resources for preparation, validation and implementation of integrated pest management (IPM) programmes for different environments, cropping systems and social-economic conditions.

NEEDS FOR DEVELOPMENT OF AN INDIGENOUS SCIENTIFIC AND TECHNOLOGICAL CAPABILITY FOR IPM

Pests and diseases cause heavy preharvest and postharvest losses in Africa—ranging from 10 per cent upto 80 per cent. To reduce these losses in future, there will be increasing demand for chemical pest and disease control materials, much of which has undesirable environmental effects. Planned programmes of pest control are therefore necessary, using limited quantities of pesticides, but increasingly relying on cultural and biological control. Crop protection services in Africa should be more involved in detecting pests, recommending pest management strategies and implementing treatments. They are also responsible for quarantine, pesticide regulation and the in-service training programme.

Only high-quality researchers and practitioners can provide extension workers and farmers with new intensive information, efficacious technology, ecologically acceptable and sustainable integrated pest and vector management systems. The new IPM systems should be completely consonant with Africans' traditional knowledge base, socio-cultural framework and yet lead to enhanced productive crop and livestock agriculture and reduce hazards caused by medical vectors (Odhiambo, 1989).

Our questionnaire distributed to six selected countries confirmed the actual shortage of qualified staff working on crop pests and vectors in the agricultural research systems (Table 1).

In the past there were not many opportunities for human resource development in IPM in Africa. The majority of M.Sc. and Ph.D. students were sent to the developed countries, following a general trend in the donor policy for advanced education and training. This trend is no longer valid for many disciplines. As a UNDP/IBRD (World Bank) technical mission found out in

Table 1. **Scientific staff engaged in research on IPM of crop pests and vectors**

	Crop Pests					Tsetse					Livestock Ticks				
	Ph. D.	M.Sc.	B.Sc.	S. Tech	Tech	Ph.D.	M.Sc.	B.Sc.	S. Tech	Tech	Ph. D.	M.Sc.	B.Sc.	S. Tech	Tech
Ethiopia	3	6	15	20	25	1	2	–	–	–	–	–	–	–	–
Rwanda	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–
Somalia	–	1	5	2	2	–	–	–	–	–	–	–	–	–	–
Uganda	2	7	8	–	–	1	1	1	1	–	–	1	2	2	–
Zambia	3	4	3	6	10	1	4	3	–	11	1	3	3	1	15
Zimbabwe	3	7	2	–	6	6	2	7	3	8	–	1	2	1	4

1985, donors collectively were spending US$100 million a year in Somalia to support 1200 technical assistance personnel and on training of Somali nationals in America and Europe. This model of technical assistance of advisors and training in environments unrelated to the national problems, is reported to have had no effect in the development of national capacity of Somalia and it does not address the long-term problem of developing national institutions (Anonymous, 1989).

On the other hand the World Bank is reporting that agricultural institutions presently provide inadequate training to students in most African countries. After graduation students usually prefer to join the public service rather than become farmers. Jobs in the private agricultural sector are scarce. The costs of training are high and often too broad and theoretical. For example, universities in the Sahel (Burkina Faso, Mali, Niger and Senegal) provide 4–5-year training programme with 3 or 4 options: agriculture, forestry, animal husbandry or veterinary sciences. In the overall training of the specialisation in agriculture, crop protection disciplines are only one of the many subjects taught. Some specific knowledge on one aspect of crop protection may be obtained during a short practical training period. Most of the staff of extension services, crop protection services, research and training centres, dealing with crop protection have received such general training. A specialisation in crop protection can only be obtained outside the Sahelian zone (van Huis *et al.*, 1987).

THE ICIPE MODEL OF CAPACITY-BUILDING

The ICIPE, since its inception in 1970, has continuously been working on establishing an alternative capacity-building model based on training in a proper environment; on partnership with African universities (as well as Universities in the developed countries) and on networking with national research institutions. It is based on the utilisation of indigenous resources to train scientists within the environment of the developing countries; on the pest problems of the tropics and associating the scholars throughout their training with the people (both extension and farming households).

As a centre of excellence, the ICIPE contributes to the development effort in Africa in two ways: (i) research and (ii) training in the management of major insect pests of crops and vectors of both human and livestock diseases. The ICIPE's goal in research is to develop an integrated management system, clearly understanding that this technology system is a containment, long-term measure rather than a pest or vector eradication measure.

ICIPE's training and education philosophy is based on the premise that, ultimately, Africans themselves must provide the solutions to the challenges of economic development, and specifically to problems posed by insect pests and human and livestock disease vectors. It is for this reason that during the last 20 years, ICIPE has occupied a frontline position in the development of capacities in insect science leadership and practice. The training and education programmes at the ICIPE are tailored to suit the needs of National Agricultural Research and Extension Systems, universities and resource-poor rural communities. The following are current education and training thrusts: (i) higher degree (leadership) training; (ii) non-degree training, (iii) professional development scheme; and (iv) interactive on-site (applied research) training. These programmes have been planned and established in partnership with the users both in identifying the needs of the people and in developing the programme activities.

LEADERSHIP TRAINING THROUGH THE AFRICAN REGIONAL POSTGRADUATE PROGRAMME IN INSECT SCIENCE (ARPPIS)

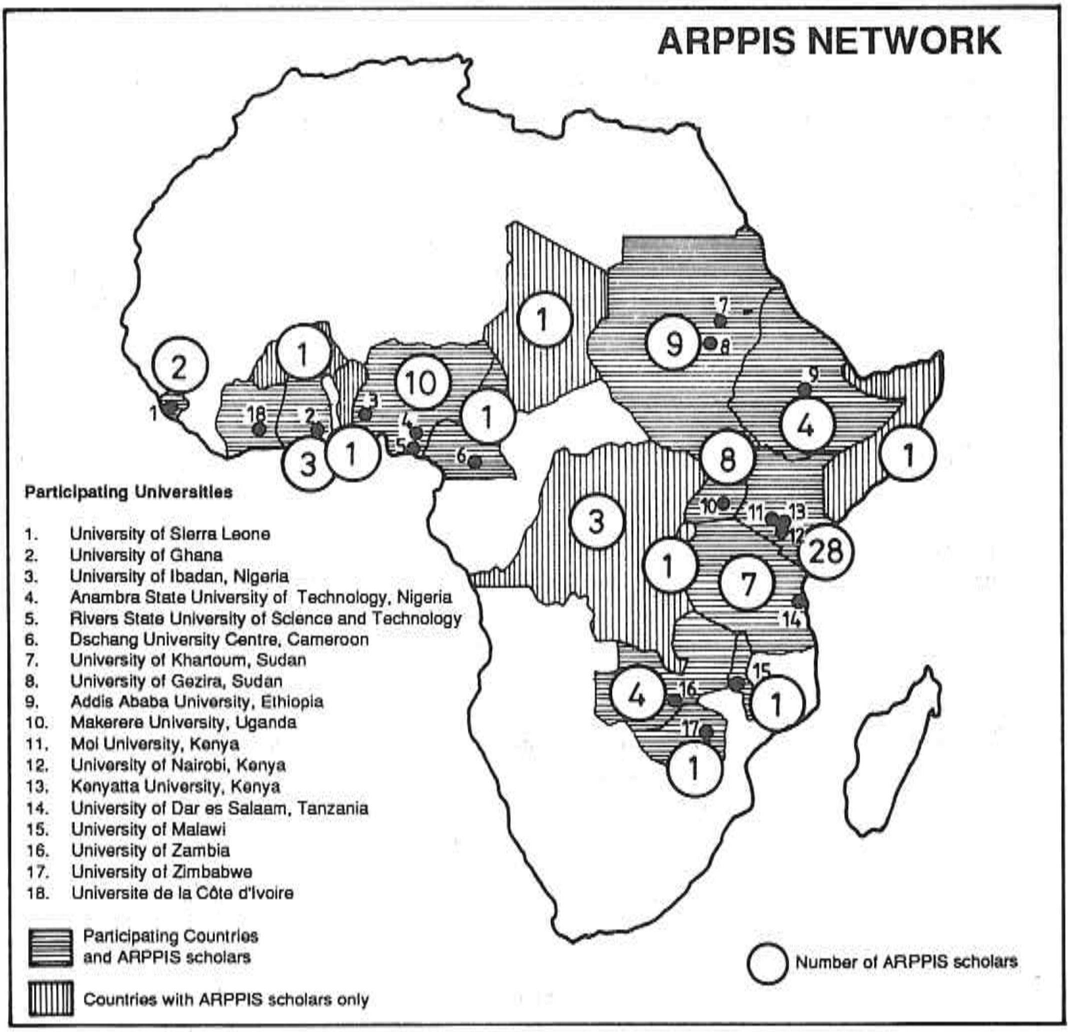
The International Centre of Insect Physiology and Ecology (ICIPE) together with currently 18 African universities, have established, since 1983, the African Regional Postgraduate Programme in Insect Science (ARPPIS) — a three-year Ph.D. training programme in insect science and related areas. It is a programme in which scholars register for a Ph.D. degree at an ARPPIS Participating University but work at the ICIPE. Between 8 and 10 students join ARPPIS each year for a three-year programme but more recently the enrolment increased to 15. From 1983 to 1991, 86 students from 18 African countries registered in the ARPPIS Programme (Fig. 1).

The students undertake a six-month course work. This is examined and assures that the students, who come from a wide background of disciplines, achieve a reasonable understanding of subjects relevant to insect science. The research projects on the biology, ecology, physiology and behaviour of insect pests and vectors that attack man, his crops or his livestock in Africa are undertaken and supervised at the ICIPE (Table 2).

The success of ARPPIS in building scientific leadership in Africa is demonstrated by three fulfilments:

(a) of the forty-eight students who have completed the course to March 1991 all are working in Africa; 25 ARPPIS students have been awarded

***Fig. 1.* Universities participating in the ARPPIS programme; number of Ph.D. students and their home countries**



their Ph.D. degree from the Participating Universities; 8 have submitted their theses and are waiting to defend their work and 11 are finalising their theses prior to submission. A critical mass of well trained scientists is being created (Table 2);

(b) as an expansion of ARPPIS and its impetus, the universities collaborating with the ICIPE are forming sub-regional centres to assist groups of universities offering M.Sc. degree in Insect Science.

***Table 2*. Research projects of ARPPIS scholars and subsequent careers of ARPPIS graduates (All scholars were engaged on Ph.D. projects, unless indicated)**

Research programme, name of scholar and year of entry	Research project	Present position
Termite Research		
1983 Class		
R. K. Bagine	Biosystematic studies of the termite genus *Odontotermes* with special reference to Kenya	Head, Department of Entomology, National Museums of Kenya
Medical Vectors		
1983 Class		
W. S. Forawi	Studies on *Leishmaniae* of lizards	Lecturer, Omdurman University, Sudan
1985 Class		
I. Aniedu	Ecology of malaria vectors in relation to an irrigation scheme in Baringo District, Kenya	Lecturer, Anambra State University of Technology, Nigeria
M. Basimike	Studies on the factors affecting the distribution and abundance of phlebotomine sandflies in a leishmaniasis endemic focus in Baringo District, Kenya	Postdoctoral Fellow, ICIPE, Kenya
1987 Class		
V. Nyambati	Inter-relationships between *Leishmania* species: molecular karotype analysis	Lecturer, Jomo Kenyatta University College of Agriculture and Technology
1988 Class		
A. Onyido	The ecology of *Sergentomyia garnhami*: a vector of leishmaniasis in Kenya	

☞

Research programme, name of scholar and year of entry	Research project	Present position
B. Rapuoda	Ecological and behavioural studies of mosquito species in the Mwea Irrigation Scheme, with special emphasis on *Anopheles arabiensis*	
Tsetse		
1983 Class		
J. Nyeko	The influence of mode of transmission of *Trypanosoma congolense* on the stability and induction of resistance to Samorin	Research Officer, Tsetse Control Department, Ministry of Animal Industry and Fisheries, Uganda
1984 Class		
U. Elneima	Characterization of different strains of *Trypanosoma congolense* collected from the Lambwe Valley, Western Kenya and Nguruman area, Maasailand, Kenya	Entomologist, Ministry of Livestock, Sudan
D. A. Adabie	Pupal ecology and the role of predators and parasitoids in natural population regulation of *Glossina pallidipes* at Nguruman, Kenya	Entomologist, Ghana Atomic Energy Commission, Ghana
1985 Class		
C. Kyorku	Trapping studies on *Glossina longipennis* Cortie at Nguruman, South-western Kenya	Lecturer, University of Ghana
R. Sang	*In-vitro* studies on the virus-like particles (VILPs) of the tsetse fly *Glossina pallidipes* (Austen) (Diptera, Glossinidae)	Research Officer, Virus Research Centre, Kenya
G. Tikubet	The ecology of *Glossina* spp. and trypanosomiasis challenge in southwestern Ethiopia	PESTNET Resident Scientist, Ethiopia

Research programme, name of scholar and year of entry	Research project	Present position
1986 Class		
P. K. Muange	Factors affecting the pupal distribution and mortality in a natural population of *Glossina pallidipes* (Austen), at Nguruman, Kenya	Research Officer, Division of Vector-Borne Diseases, Kenya
1987 Class		
J. O. Davis-Cole	Some aspects of the mating behaviour of *Glossina morsitans morsitans* Westwood and *G. pallidipes* Austen	Research Associate, Tsetse Research Programme, ICIPE, Kenya
M. I. Mwangelwa	The ecology and vectorial capacity of *Glossina fuscipes fuscipes* on Rusinga Island and along the shores of Lake Victoria	Scientific Officer, Tropical Disease Research Centre, Zambia
1988 Class		
K. Mugwe	Factors involved in trypanosome differentiation in the tsetse midgut (withdrew from ARPPIS in 1989)	
S. Siziya	Modelling the movement and distribution of tsetse flies on the Nguruman Escarpment, Kenya	
J. Abu-Zinid	Predation of tsetse in the vicinity of traps used for the control of *Glossina pallidipes* Austen	
Livestock Ticks		
1983 Class		
A. A. Latif	Host relationships of the tick *Amblyomma variegatum* in cattle and rabbits	Scientist, FAO Livestock Project, Zimbabwe

☞

Research programme, name of scholar and year of entry	Research project	Present position
B. C. Njau	Studies on the resistance acquired by rabbits experimentally infested with *Rhipicephalus evertsi*	Postdoctoral Fellow, ILCA returned to TALIRO, Tanzania
1984 Class		
C. Maranga	Studies of *Rhipicephalus appendiculatus* Neumann immunity in goats	Lecturer, Kenyatta University
1985 Class		
B. Wishitemi	Induction of immunity in sheep to *Rhipicephalus* Neumann antigens	Lecturer, Moi University
1987		
S. Mbogo	Induction of resistance to ticks by the immunization of their hosts with commercially available moulting hormone, and other tick antigens	Vet. Research Officer, Kenya Agricultural Research Institute (KARI), Vet. Research Division, Muguga, Kenya
E. Mwangi	The ecology of non-parasitic stages of *Rhipicephalus appendiculatus*, and other ticks of livestock, and the role of predators, parasites, pathogens and climatic factors, in the regulation of natural populations	Research Associate, Livestock Ticks Research Programme, ICIPE
H. Oranga	Stochastic modelling of the impact of tick infestation on cattle productivity under natural field conditions on Rusinga Island	Biostatistician, African Medical Research Foundation (AMREF), Nairobi
1988 Class		
S. M. Kheir	Mechanisms of cutaneous reactions in cattle infested with *Rhipicephalus appendiculatus*	

☞

Research programme, name of scholar and year of entry	Research project	Present position
1989 Class		
H. Kiara	Membrane bound proteins of the midgut of *Amblyomma variegatum* Fabricius, 1974 (Acarina, Ixodidae): Proteins responsible for induction of immune protection of the host against infestation of homologous and heterologous species	
Crop Pests		
1983 Class		
S. Kyamanywa	Ecological factors governing insect pest populations in maize and cowpea crop mixtures with special reference to the bean flower thrips *Megalurothrips sjostedti*	Lecturer, Makerere University, presently PESTNET Resident Scientist, Kenya
S. H. Oketch	Colonizing responses in *Maruca testulalis* to different cowpea cultivars in relation to their resistance or susceptibility	PESTNET Resident Scientist, Zambia
J. Okeyo-Owuor	Population ecology of the legume pod borer *Maruca testulalis* in relàtion to its natural enemies on cowpea in Western Kenya	PESTNET Resident Scientist, Somalia
1984 Class		
J. H. Nderitu	Responses of the common bean (*Phaseolus vulgaris*) cultivars to beanflies (Diptera: Agromyzidae)	Entomologist, Ministry of Agriculture, Kenya
M. Ogengo-Latigo	The influence of some cultural practices and aphid natural enemies on the infestation of the common bean (*Phaseolus vulgaris*) by the bean aphid (*Aphis fabae*)	Lecturer, University of Malawi

☞

Research programme, name of scholar and year of entry	Research project	Present position
L. Kantiki	Studies on some aspects of the biology and feeding behaviour of *Eldana saccharina* Walker (Lepidoptera: Pyralidae) on one maize and one sorghum cultivar	
J. Bahana	Bioecological studies on *Dentichasmias busseolae* (Hymenoptera, Ichneumonidae) the parasitoid of *Chilo partellus* and its potential for biological control	Research Scientist, International Red Locust' Control Organisation for Central and Southern Africa, Zambia
J. F. Omollo	The biology and host-parasite relationships of an entomogenous nematode, *Panagrolaimus* sp.	Lecturer, Kenyatta University
1986 Class		
E. Minja	Studies on the effect of intercropping sorghum and cowpea on the population patterns of the stem borer complex	Scientific Officer, Ministry of Agriculture, Tanzania
G. Akpokodje	Orientation and feeding behaviour of phytoseiid predators on cassava green spider mites (*Mononychellus*). (Withdrew from ARPPIS in 1988)	
F. N. Ndonga	Population dynamics of the cassava green spider mite *Mononychellus tanajoa* in relation to its natural enemies	Research Officer, Ministry of Agriculture, Kenya
E. Karamura	Studies on the orientation, feeding behaviour and development of the cassava green spider mite *Mononychellus tanajoa* (Tetranychidae; Acari)	Research Officer, Ministry of Agriculture, Uganda

☞

Research programme, name of scholar and year of entry	Research project	Present position
M. Wa Macharia	Crop losses in maize caused by the maize stem borer *Busseola fusca* Fuller (Lepidoptera, Noctuidae) in the Rift Valley, Kenya	Research Officer, Ministry of Agriculture, Kenya
M. Gethi	The effect of intercropping resistant and susceptible cowpea cultivars with maize and time of planting on infestation and damage by the legume pod borer, *Maruca testulalis*	Research Officer, Ministry of Agriculture, Kenya
M. Njau	Endocrinology of development and reproduction in the maize stem borer, *Busseola fusca* Fuller (Lepidoptera: Noctuidae)	Tutorial Assistant, University of Dar-es-Salaam, Tanzania
E. Nwofor (M.Phil)	The biology and behaviour of *Neoseilus idaeus* (Denmark and Muma) (Acarina: Phytoseiidae) reared on natural and artificial media	
R. Bob-Manuel (M.Phil)	A morphometric study of the cassava green spider mite complex, *Mononychellus* spp (Acari: Tetranychidae) in Africa	
1987 Class		
T. Murega	Genetic incompatibilities among populations of the cassava green mite complex, *Mononychellus* spp (Acarina: Tetranychidae) and their implications for the taxonomy of the mite	

☞

Research programme, name of scholar and year of entry	Research project	Present position
J. Ogwang	The survival of *Nosema* sp under field conditions of its effects on the reproductive potential of *Chilo partellus*	Scientific Officer, Ministry of Agriculture, Uganda
P. N. Amifor (M. Phil)	Biology and predation efficiency of an aphidophagous coccinellid *Cheilomenes lunata* on the cowpea aphid (*Aphis craccivora*)	
B. O. Odongo (M. Phil)	An entomopathogenic fungus (Fungi Imperfecti) as a potential biocontrol agent of *Mononychellus tanajoa*	
K. O. Kambona (M. Phil)	A biochemical investigation of the taxonomy of the cassava green spider mite *Mononychellus* spp (Acari: Tetranychidae) in Kenya	
G. R. S. Ochiel (M. Phil)	Biology of *Trichogramma* species near *exiguum* Pinto and Platner (Hymenoptera: Trichogrammatidae) on some lepidopterous hosts in South Nyanza, Kenya	
1988 Class		
M. Chumvwa	Contribution, and inheritance, of the major components of resistance in certain maize cultivars to the stem borer *Chilo partellus*	
A. Malik	Studies on some pathological aspects of the fungus *Beauveria bassiana* on the legume pod borer *Maruca testulalis*	

☞

Research programme, name of scholar and year of entry	Research project	Present position
A. Kanu (M. Phil)	The pathogenicity of local isolates of *Bacillus thuringiensis* to some non target invertebrate organisms	
S. Kamara (M. Phil)	The development of artificial media for the production of *Hirsutella* sp (Fungi Imperfecti) for the control of the cassava green spider mite, *Mononychellus tanajoa*	
J. Mbapila	The infectivity of *Beauveria bassiana* on *Chilo partellus*	
A. Ngi-Song	The dynamics of *Chilo partellus* parasitized by a Kenyan strain of *Trichogramma* sp under experimental conditions using sorghúm as the host plant	
1989 Class		
R. Bob-Manuel	Effect of an entomopathogenic fungus — *Hirsutella thompsonii* Fisher (Fungi Imperfecti) on the dynamics and control of cassava green mite (CGM) — *Mononychellus tanajoa* Bondar (Acari: Tetranychidae)	
F. G. Nwilene	Population density and dispersal pattern of cassava green mite, *Mononychellus tanajoa* with special reference to the potential of the predatory mites, *Iphiseius degenerans* as a biological control agent	
A. El Badawi	Inheritance and combining ability of resistance to sorghum shootfly, *Atherigona soccata* and spotted stem borer, *Chilo partellus* in sorghum	

☞

Research programme, name of scholar and year of entry	Research project	Present position
A. N. Duale	Biology of *Pediobius furvus* and its biological potential against cereal stem borers	
E. A. R. Ndhine	Studies on bionomics and behaviour of *Tetrastichus sesamiae* and its potential in biological control of legume pod borer, *Maruca testulalis*	
B. Uronu	The effect of plant resistance and cultural practices on population densities of banana weevil *Cosmopolites sordidus* (Germ) and on banana yield	
A. S. S. Mbwana	Investigation of the host range, survival and control of *Pratylenchus goodeyi* (Sher & Allan) on banana	
Sensory Physiology		
1988 Class		
C. Mugoya	The feeding behaviour of *Maruca testulalis* larvae on cowpea (*Vigna unguiculata*)	
1989 Class		
D. D. S Bawo	The role of sensory receptors in mating and oviposition behaviour of *Maruca testulalis* (Geyer)	
Chemistry and Biochemistry		
1985 Class		
B. Torto	Allelochemicals from *Sorghum bicolor* that stimulate feeding by the larvae of the stem borer *Chilo partellus*	Research Scientist Locust Research Programme, ICIPE
H. M. Hassane	The biochemical taxonomy of phlebotomine sandflies (Diptera: Psychodidae) in Kenya	Postdoctoral Fellow, Locust Research Programme, ICIPE

(c) ARPPIS is an effective network and is seeking financial resources for a Postdoctoral Award Scheme to support its graduates with scientific travel, research or teaching materials, preparation of manuscripts. Grants are needed for this scheme which is a sure way of stemming the brain drain from Africa.

NON-DEGREE TRAINING

The short courses for practitioners provide training in specialised areas of insect science for which the ICIPE has expertise. They present up-to-date knowledge and practical experience in field and laboratory, research and IPM technology development and implementation. A proportion of places in the courses is offered to past ICIPE graduate students to sustain and encourage their commitment to research.

Since 1977, the ICIPE has provided training to 466 practitioners from Africa and the tropical developing world. The majority of courses organised between 1987–1990 were on integrated pest and vector management and 120 practitioners and scientists from 17 developing countries have attended the ICIPE courses (Table 3). Courses which consist of lectures, laboratory and field practicals, and field excursions are given by ICIPE staff and collaborating institutions (ILRAD, African universities, European universities, National Agricultural and Veterinary Research Institutes). The course programmes include also seminars and lectures given by trainees to build-up their experience as future trainers in their national programmes. The list of courses on pest and vector management presented at the ICIPE is given in Table 3.

PROFESSIONAL DEVELOPMENT SCHEME

The Postdoctoral Research Fellowships are offered to young scientists from anywhere in the world to provide them with the opportunity to work with ICIPE scientists for periods of up to 2–3 years in a tropical environment on some of the major insect pests and vectors of Africa; and thereby contributing specialised skills and knowledge to the ICIPE research programmes. A welcome consequence of the scheme is the continuous creation of a world-wide network of future collaborators.

Since 1987, 20 postdoctoral research fellows from 9 countries have worked at the ICIPE: Canada (1), Ghana (2), India (2), Kenya (5), Nigeria (2), Poland (1), Sudan (2), Tanzania (1), Uganda (1), United Kingdom (1), USA (1), Zaire (1). They have been attached to the following research programmes and units:

***Table 3*. ICIPE international group training courses in pest and vector management 1987–1990**

Year	Course title	Course duration	No. of participants	No. of countries represented
1987	Components Essential for Ecologically Sound Pest and Vector Management Systems	3 weeks	26	10 countries and India
1987	Insect Endocrinology	3 weeks	9	Egypt, Ghana, Kenya, Nigeria, Sudan, Tanzania
1987	Use and Safe Handling of Radioisotopes in Insect Sciences	3 weeks	10	Kenya, Uganda, Tanzania, Zambia
1987	Use of Microbial Pathogens in the Control of Insect Pests and Vectors	3 weeks	9	Egypt, Ethiopia, Kenya
1988	Group Training Course on Pest and Vector Management Systems	3 weeks	33	14 Tropical developing countries
1989	Tick Management Course	4 weeks	9	Kenya, Uganda, Zambia
1989	Regional Training Course on Insect-Related Data Management	2 weeks	8	Burundi, Rwanda, Tanzania, Uganda
1990	Tsetse Management Course	6 weeks	7	Kenya, Sudan, Zambia
1990	Regional Training Course on Insect-Related Data Management	2 weeks	8	Burundi, Rwanda, Tanzania and Uganda

Crop Pests (8), Medical Vectors (2), Livestock Ticks (3), Tsetse (2), Chemistry and Biochemistry (3), Cell Biology (1), Sensory Physiology (1), Social Sciences (2). One postdoctoral fellow from India, attached to Crop Pests Research Programme, has worked on the collaborative ICIPE/IRRI project on rice rollers, based at IRRI, Philippines.

The second type of the project — Research Associate Scheme — gives scientists from national research programmes and universities the opportunity to work at the ICIPE for a period of 6 months. This scheme is of particular value to national staff of PESTNET participating countries and its objective is to improve the exchange of knowledge and the inter-African collaboration. Participants are involved in research development and validation of pest and vector management packages.

INTERACTIVE ON-SITE (APPLIED RESEARCH) TRAINING

In this programme, ICIPE researchers and their counterparts within the NAR & ES work jointly on a specific insect pest or vector management problem. This programme is undertaken under the auspices of the Pest Management and Development Network (PESTNET). The programme is aimed at promoting interaction and synergism in search for ecosystem specific and socio-economic pest management technologies.

DISCUSSION

The ICIPE through the Institutional Building and Interactive Research Unit (IBIRU) is strengthening national programmes in Africa in a number of ways:

- by human-resource development by providing long, intermediate and short-term training;
- by enlarging the current awareness of IPM by providing relevant scientific information, training and extension materials;
- by establishing ARPPIS Scientific Network and expanding PESTNET collaboration.

African Regional Pest Management R & D Network (PESTNET) for Integrated Control of Crop and Livestock Pests was established in 1987. Already it has contributed significantly to strengthening national research capabilities by collaborative research programmes in Somalia, Zambia, Rwanda and Ethiopia. The network in the second phase of the project will have four zones in operation (Eastern, Southern, Central and West-Coastal Africa). The Network will not only require training in IPM related disciplines, but also in documentation and information. To meet the most urgent training needs of PESTNET countries, IBIRU has already carefully selected courses upgrading skills of national scientists in IPM in the next five years. However, pest management is a dynamic system and needs to be revised and up-dated continuously, implying that the training requirements are assessed periodically and modified according to new development in IPM technologies.

ACKNOWLEDGEMENTS

I wish to acknowledge the help given to me in assessing the present status and future training needs in IPM by Drs: G. Tikubet (Ethiopia), V. Okoth (Uganda), Z. Sithole (Zambia), H.A. Farrag (Sudan) and Mr. A. Chalabesa (Zambia), and Dr. P. Capstick (ICIPE Deputy Director) and Dr. E. Omolo (PESTNET Co-ordinator) for helpful discussions during preparation of the manuscript for publication.

REFERENCES

Anonymous (1989). Agriculture: The primary source of growth and food security. In *Sub-Saharan Africa, from Crisis to Sustainable Growth. A Long-Term Perspective Study*. The World Bank, Washington, DC, pp 89–107.

Odhiambo, T. R. (1980). Perspectives and Futures: An African Perspective. In *Faith and Science in an Unjust World* (Report of the World Council of Churches' Conference on Faith, Science and the Future, MIT, Cambridge, USA, 12–24 July 1979), Vol. 1, Plenary Presentations, pp 159–170, (Ed. Roger L. Shinn), Geneva, Switzerland: World Council of Churches.

Odhiambo, T. R. (1987). Welcoming and Opening Address. In *Eastern and Southern Africa Agricultural Research Review*, World Bank 1985–86, pp 101–106, World Bank, Washington DC, USA.

Odhiambo, T. R. (1989). Strategies for sustainable pest management in Africa. In *Proceedings —Africa in Wageningen. The Agricultural Development of Africa; Its Challenges and Constraints, The African Point of View*, Wageningen Agricultural University, 1989, pp 3–9.

Van Huis, A., N. Kane and L. Den Boer (1987). Needs and constraints of crop protection training in the Sahel. *Insect Sci. Applic.* 8, 937–942.

Gender Constraints Upon Receiving and Disseminating Agricultural Information: The Role of Women

T. Gabriel

University of Wales, College of Cardiff
P. O. Box 924 Cardiff CFI 3UY, UK

SUMMARY

Understanding of womens' roles in agricultural, economic, and social processes is crucial if development objectives are to be met. The effectiveness of pest management strategies can be improved by building upon the indigenous knowledge and skills of local women participants.

This paper reviews briefly why womens' roles need to be given serious consideration in planning agricultural changes, including pest management. With recognition of the need for better rural extension services, an example from women participants in extension is presented. This outlines some important needs and makes recommendations for sustainable practice both in service delivery and for staff themselves. Key issues focus upon data needs, organisational constraints, and problems of attitude. Priorities for involving greater participation by women include management; extension; use of media; and gender awareness.

INTRODUCTION

Agricultural information must be relevant to the needs of its users. These needs are likely to be influenced, amongst other social factors, by the gender of farmers/users. Consequently, gender awareness, especially of the complex economic and social roles of women, must be included in planning, implementing and monitoring information flows. Rural women are likely to work at the very centre of production processes, yet their role is too often "invisible" to those who design and direct agricultural information.

Discussion below looks first at why women's roles need to be taken seriously in planning agricultural development, including pest management. An emerging priority (Jiggens, 1983; Weidemann, 1987) is the need to design better agricultural extension services and target information, both for women farmers and for service members themselves. However, relatively little is known of constraints and problems here. The second part of the discussion reviews briefly some recent conclusions from field experience of female extension staff from several African, Caribbean and Pacific (ACP) countries.

1. ECONOMIC AND SOCIAL SIGNIFICANCE OF WOMEN'S ROLES

Women work at the very heart of developing countries' economies (Dixon, 1982). Although estimates vary, they grow at least half of the world's food (in Africa, some 80% of food produced), dominating the nutrition process of their households and communities with food processing, preservation and preparation. In hours of backbreaking labour they supply households with food, water, fuel and housing and frequently to generate cash income to satisfy basic household needs. Yet rural women are likely to be numbered amongst the least healthy, least educated and lowest in the chain of access to food. Women's central contributions to their communities are overlooked too by designers of economic and social development programmes, with the result that women have only limited access to the innovations, training and other basic resources that could facilitate their tasks and increase their productivity.

The number of farmers who are also women is large. Additionally too, a significant proportion of these are small, resource-poor farmers. Their productivity, efficient use of resources, and the impact of recent "development" changes upon their roles, responsibilities and status are all significant to sustainable agricultural development. Any improvement in the situations of rural women in developing countries then will produce a significant impact upon agricultural productivity and decision-making about fertility behaviour. Not only is the neglect of gender aspects of production inefficient, but socio-economic change is assigning new roles and responsibilities to women, as well as removing their power for controlling their own resources. Women too have a key mediating role in household welfare and nutrition; and female production is substantial but undercounted and undervalued.

In any discussion about the role of women, efficiency is often seen as the prime reason for drawing women into economic activity. It is quite simply inefficient not to make use of the latent productive abilities of women. However, economic self-determination based upon mainstream economic activity is not the only benefit perceived by women, and it can often be the springboard to a more equitable distribution of community decision-making.

Progress in exploring women's contributions to their societies has of course already begun. Between 1975 and 1985, the United Nations International Decade for Women drew attention to their specific needs. At the UN World Conference on Agrarian Reform and Rural Development (1979) for instance, problems faced by rural women were recognised and a plea entered for better statistical data about their role in rural activities. For the African, Caribbean and Pacific countries, Lome III, the 1985 ACP-EEC Convention, is the first to mention specifically the needs of women in development activities. Article 123 (2) notes a requirement to provide women with access to all aspects of training as well as other resources for alleviating the backbreaking nature of their tasks. This focus upon training, especially in the dissemination of information about rural women, was selected for special attention in the final statements about future strategies from the UN International Decade for Women (Purvis, 1986: 13–14). For the process of including women more adequately in development, rural extension education is recognised to be essential.

For rural extension, however, beliefs that benefits from a male-oriented extension service will "trickle down" somehow from men to women have been shown to be impracticable. The FAO for example, has calculated that in sub-Saharan Africa where women represent nearly half the agricultural labour force (47%), only 3% of agricultural advisers are female. In Asia where women account for 45% of the rural labour force, only 0.7% of extension advisers are women (Development Forum 1987: 15). These gender disparities are important. Neglecting gender constraints upon flows of information about innovations and new technologies seriously impedes the professional effectiveness of extension services.

The urgent need to include women more adequately in rural extension activities is clear. As farmers, women often find themselves in a set of circumstances very different from men. Performing specific roles in their societies with particular economic and social responsibilities, their abilities to be involved in agricultural production may be affected. In order to work with women in rural extension, new and different methods of advice or management, or adapted recommendations may be called for. This requires rural extension/

development organisations to be more aware of the situation in which rural women work so as to focus their advice and recommendations more appropriately.

LEARNING ABOUT RURAL WOMEN

Learning adequately about rural women is essential because of the nature of their responsibilities. A basic feature of indigenous rural societies is that the family/household is the unit through which people seek to fulfil their needs and to improve their situations. Another basic feature is that duties within the family/household usually are directed along gender lines, amongst females and males, a division of labour often referred to as "complementary". But although familiar, this concept may not explain situations fully enough to be useful in interpreting many features of rural life. Responsibilities to the family/household for each gender usually include production or provision and control or management of the resources needed to carry out their work.

Rural women's work takes various forms, according to their particular rural environments and cultures (Nelson, 1979). In most cases it may include child-bearing and rearing; household provisioning and management (cooking, cleaning, washing clothes, household repairs and manufacture, fuel-gathering, wood collecting); aspects of agricultural production and processing; livestock raising; artisan production; trade; income generation. These tasks are not perceived by the participants as separate (familial/non-familial, domestic/economic, non-productive/productive), but rather as all intrinsically related. For women, child-bearing and rearing are matters of maximising family opportunities for survival and security through decisions regarding numbers of children, their education, health care and kinds of work that they will do.

Some of the means by which women provide the resource base for undertaking their family responsibilities include subsistence production of resources for household consumption; participation in income-generating work; and traditional, largely female-run systems of mother and child health care. As economies and directions of opportunities have become monetarised and mechanised, women are less able to meet their responsibilities through subsistence production alone. Reports from rural women's projects in many regions suggest that women are seeking opportunities to increase their incomes and that they are spending their income on basic family/household needs: food, repairs/improvements, clothing, children's education.

As for men, women's access to and control over resources affects the degree, the mode and the quality of their interaction. Any shifts in the wider economy, planned or unplanned, may create very different impacts for women and for men. By only considering the behaviour of men or assuming that this includes women, planners have collected only half of their data.

Rural development policies, whether in agriculture, land tenure, employment, population, health or other areas which do not recognise and support the resource needs of each sex, that is, promoting a genuine complementarity of the rural household/family will not have their intended effects. Indeed they may have unintended negative side effects. For instance:

(i) **Rural employment.** Few data are available on women here. How many participants are women? What is the rate of unemployment increase? Is there any recognition that women's earnings are an indispensable source of income to poorer families, or that women's income is usually spent on her household's most basic needs?

(ii) **Food production.** Many misconceptions abound. For instance, who is engaged in food production, or in aspects of it? Who owns the land? What technology is used? Who makes the decisions? On what basis are decisions made? Lacking answers to these questions, the resulting misdirected programmes of increased food production (inappropriate) extension activities, development institutions, credit arrangements) continue to be well-documented.

(iii) **Fertility.** Women's resource needs and their means of meeting them have as much to do with desired family size as those of men or "the family". Both a woman's point of view about preferred family size and her willingness to act upon this preference are influenced by her access to valued resources, and her control over them throughout her life vis-a-vis males. Her economically-based "social" preference for a large family may be related also to competition for her husband's favour within a polygamous marriage; to the need for children to undertake her subsistence work while she earns money; or to dependence on males for all contact with the outside world. Conversely, her desire for a small family may be related to her perception as a wage labourer of the finite nature of the resource base.

Institutions implementing programmes for women will sometimes display the same lack of understanding. Institutions can succeed only if their project objectives are closely related to the needs and desires of the group they serve. Too frequently, they fail to see or recognise women's co-equal role in the rural household/family. For instance, family planning programmes often contain small numbers of eligible women and have high drop-out rates. These are accounted for in part by differences in perspectives on the use and programme (what kinds of family planning are feasible; what delivery modes are sustainable in the rural women's situation where little attention is paid to what rural women need). Under-use of rural health clinics may be one indication. Another kind of institution directly involving rural women is the womens' group or a women's component of rural development activities. Typically these programmes consist of information and services relating to literacy, nutrition, child-welfare, home economics, labour-saving technology; and more recently, income-generating projects. Yet groups that emerge from the needs of the women participants themselves, and often have different priorities from those conventional programmes directed at women based upon expressed needs, are most likely to be successful.

However, concepts of rural development so far have failed to include the centrality of women's roles in predicting and explaining rural socio-economic behaviour. For this reason, although research about rural women is undertaken in many places, strong indications exist that recognition of the importance of that research is not occurring. For example:

(i) although this information is being disseminated, it is not being read or incorporated into the thinking of most rural planners; at best it is tolerated as a "fashion" or put into a separate chapter in the report;

(ii) studies of rural women do not carry the high status of other subjects like migration, nutrition, cropping patterns or household economics for instance;

(iii) studies are often difficult to undertake through lack of access and lack of data.

Learning about rural women is not impossible, though a lack of attention generally to rural phenomena hinders this work. It is important to discover what women themselves believe that they need. Here institutions or projects that have already made this contact may be helpful, e.g.: familiy planning clinics; rural health centres; agricultural and rural extension services;

functional literacy schemes. As Nelson (1979) has reminded us, rural women's needs are likely to vary widely according to their social, cultural and economic environments. Rural women are not an homogenous group.

Since the early 1970s the attention of researchers, planners and policy makers has been focused increasingly upon the situation of women in developing countries, and their participation in the development process. This growing interest, stimulated in part by the UN International Decade for Women (1975–85) has produced a wealth of studies bearing witness to the key role that women play in social and economic development through their productive activities, their domestic labour, and in their capacity as bearers, carers and socialisers of the next generation. The same studies have revealed too the relative powerlessness of women in development decision-making, and have shown that some forms of "development" actually operate to the detriment of women (Ahmad, 1980; Charlton ,1984: 32–8; Palmer, 1977).

HOW HAS DEVELOPMENT AFFECTED WOMEN ADVERSELY?

The combination of domestic, productive and reproductive roles means that many rural women in developing countries work a very long day, sometimes as much as 15 or 16 hours (Palmer, 1977: 99–100). In many cases, the introduction of modern agricultural techniques and cash crops has increased women's workload by expanding tasks such as weeding and transplanting, but without bringing women an appropriate share of cash crop payments. Women are generally excluded from new agricultural technology; farming improvements tend to be concentrated in the male sector, while women continue with traditional low-productivity methods. When time-saving mechanised devices are introduced, the tasks for which they are designed tend to be taken over by men, with the result that women lose access to a source of income. These changes enhance male prestige yet reduce the authority and status of women within the family (Boserup, 1970: 55–56; Palmer, 1977: 100–102; Ahmad, 1980: 6–8).

In recent years increasing numbers of landless individuals combined with the introduction of new technology, commercialisation of agriculture, and rapid population growth has contributed to a shortage of paid work in rural areas, and the need for the expansion of non-agricultural employment. Women have suffered particularly from this loss of agricultural work and from the replacement of traditional income-generating activities by capital-intensive modern production. In the drift to cities in search of work, women are again at a disadvantage, being driven to take non-permanent, casual work in the informal sector, unprotected by government or union regulations. As a result of the contraction of formal and informal employment in rural and urban areas, many women no longer have access to any regular source of cash income (Charlton, 1984: 127, 133).

STRATEGIES FOR CHANGE

Creating strategies designed to bring about beneficial changes in women's lives is not an easy task. The following factors have led development planners to ignore women's needs in the past.

(i) Economic and cultural powerlessness of women;

(ii) "Invisibility" of rural women's productive activities;

(iii) Male dominance in international and national development planning agencies;

(iv) The fact that women's problems often require small-scale solutions involving intermediate technology, rather than large-scale, high technology, high prestige programmes;

(v) Stereotyped notions about women by decision-makers, which may blind them to the range of available policy options.

2. IDENTIFICATION OF CONSTRAINTS AND PROBLEMS

If women's contributions to rural extension are significant for further study and action, three issues appear to be urgent at this stage:

1. Adequate identification of constraints that women face in both receiving and disseminating extension information. Much has been written about the problems that rural women face in development activities generally, but the issues facing female extension staff and their clients urgently need clarification.

2. From this initial step, the training of women for increased participation in rural development activities requires scrutiny.

3. Finally, appropriate means must be found to activate funding that recognises and improves women's contributions to agricultural progress.

A recent study of agricultural extension information for women in the ACP countries by Purvis, (1986) suggested that the following points are central.

Key areas in any plan for providing rural women with information must be a matter for careful consideration of those concerned locally, including the women themselves, as well as nationally. There are probably no globally applicable prescriptions. With that point understood, any appropriate plan would have to consider several key areas, specifically:

(i) problems inherent in the excessive work-loads of rural women;

(ii) the appropriate training required;

(iii) appropriate support services;

(iv) institutional requirements.

Assistance with these issues may be found by more detailed examination of the following points:

(i) increasing the proportion of rural girls completing their education by gaining qualifications in agriculture;

(ii) improving the extension services and related training: their organisation, management, programming and staff development;

(iii) promoting *other* approaches than "extension", including collaboration with non-government organisations;

(iv) developing closer links with research.

Points noted below are taken from a Rural Extension Workshop for African, Caribbean and Pacific women extension officers. Discussions focused first upon several constraints to information flows. There was general agreement that a wide variation in needs for information flows existed, both within and between member countries. Individuals and organisations would have, of necessity, to adapt any recommendations to their own specific circumstances.

Three issues—data needs, organizational constraints and problems of attitude —received most attention.

(i) Data needs

A major constraint to an adequate flow of information was the lack of hard data about what women do. Agencies and others involved in collecting and circulating data did not design categories specifically to take account of rural women's circumstances. Objective definitions, situational appraisals, monitoring/evaluation, and development of specific responses to problems were all constrained in this way. Recommendations formulated from such data were therefore apt to be "gender-blind".

(ii) Organisational constraints

These were seen to be limited by the "top-down" extension model which denied opportunities for horizontal-flows of information between farmers and community members. Furthermore, a lack of a holistic approach effectively denied the reality of multiple strands in rural, social and economic relationships.

(iii) Problems of attitude

A significant problem was to find ways of enabling men and women to work together, thereby influencing and altering attitudes. Furthermore, the attitude towards rural employment by rural girls who often responded to their acquisition of educational qualifications by leaving the countryside for work in town —or marrying —was seen as a major constraint.

3. RECOMMENDATIONS FOR EXTENSION PRACTICE

Participants noted their priorities in practical issues for future planning. Their perceptions for involving women in rural extension activity fell into four major categories: management, extension, use of media and promotion of gender awareness.

Management issues at national and regional level included the necessity for use of government organisations to reach women; ensuring that women themselves were the participants in needs identification and decision-making, thereby involving both extension worker and clientele in project monitoring, assessments and evaluation. Better co-ordination of assistance efforts between donors, as well as an examination of the role of expatriate organisations in relation to women's roles in programmes, was suggested. The inclusion of local level representatives at decision-making level was emphasised.

Extension strategies needed to emphasise the special needs of rural women clients. More accurate data-collection methods from women might include extended residence in village communities, and transfer of ideas by women themselves. This would permit the use of local people rather than external specialists to undertake research in their own situations. Management practice should pay attention to quantitative issues, including increasing the number of female extension workers, coordinating research and extension more effectively, and providing more adequate support for field workers. One way to do this would be to work with available resources rather than with expanding programmes.

The use of media should also be better adapted to the needs of rural women. Women need to be controllers of programme-making, with ways found to feed-back women's needs to the media. Adequate packaging of agricultural technologies might include the use of open-learning packages to solve the problem of reaching women with timely and appropriate information, and improving facilities for women's education.

Promotion of gender awareness has been established as an effective innovation. Actions here would include making use of gender-treated programmes, as well as provision of gender awareness training in extension services at all levels, including the donor agencies.

In terms of most immediate priority, three points were selected as deserving particular significance. These were the necessity of reaching rural women with appropriate and timely information; adequate packaging of agricultural technologies; and the use of media as a means of reaching village people and village extension workers.

Funding women's contribution to rural extension needed to focus upon how funding agencies could most effectively increase their commitment of funds to assist women in rural development. Development and extension staff themselves must be prepared to advise local representatives of the international agencies, for only by agencies listening to these grass-roots messages could women's contribution be accorded better facilities in their policy and project funding. For instance, policy changes in the UK Voluntary Service Overseas organisation had been organised in this manner. The Food and Agriculture Organisation of the United Nations (FAO), understanding the significance of good local communications networks in this context, had recently opened several regional/local representatives offices. In order to make the most effective use of these, correct presentation of project proposals was essential. Project applications in the correct form for processing by a specific agency were more likely to succeed, and for this reason specific guidelines to field staff were needed. Any moves to open local or regional offices by particular agencies would be useful for this purpose.

4. CONCLUSION

Any assessment of the constraints faced by women in receiving and disseminating information cannot easily be summarised succinctly. However, some of the main conclusions are worth noting here, originating as they do from regional managers and field-level staff who are familiar with the daily problems of rural extension programmes for women.

Worthy of special mention are those continuous threads in discussion which drew attention to the success achieved in woman-to-woman communications at the horizontal level (through local women's organisations). Often this kind of network can be effectively developed through extension workers.

Frequent reference was made to the need to encourage local participation in research, needs identification, and project formulation and monitoring, rather than relying on expatriate or outside personnel.

Training women to return to the village was an agreed way of using resources most effectively. Policies in rural extension need to provide sufficient incentives to encourage training women to return to working in the villages and rural community.

Continued personal professional development by extension workers was emphasised, with the improvement of knowledge and skills in using the resources available locally being noted as particularly significant.

Finally, organisations to assist in transfers and management of information flows could be established on a voluntary basis. Some kind of networking for those working with women in rural extension was suggested. Improving agricultural and rural extension services for women farmers and for women working in extension services would need to utilise all these points. But the first stage is to listen to women participants themselves.

ACKNOWLEDGEMENTS

The workshop on which these data are based, entitled "The Contribution of Women to Rural Extension in African, Caribbean and Pacific Countries" was held in May 1987 at Sparsholt, United Kingdom. This meeting was funded by the Centre for Agricultural and Technical Cooperation (CTA), Wageningen, Netherlands; and organised by the Royal Agricultural Society of England, and the British Council. The Director was Professor Tom Gabriel. Participants attending these discussions originated from Africa (Angola, Cameroon, Côte d'Ivoire, Ethiopia, Ghana, Guinea, Liberia, Madagascar, Mali, Sierra Leone, Tanzania, Zambia): Caribbean (Guyana, Jamaica): The Pacific (Fiji, Papua New Guinea) and elsewhere (Belgium, Canada, Federal Republic of Germany, France, Netherlands, United Kingdom). VSO's representative was Margaret Legum (London). FAO's representative was Dr. Marie Randriamamonjy (Madagascar). Many individuals helped to make this meeting successful, and I am grateful to all of them. For their organisational skills, discussion and advice, I wish to thank Marie Fry (British Council), Alan Jackson (CTA), George Jackson (RASE), and Sadie Taylor (RASE); and for many valuable discussions, Monica Otto (Papua New Guinea), Marie-Jose Niestan (Netherlands), John Teaiwa (Fiji), and Niels Roling (Netherlands).

REFERENCES

Ahmad, S. (1980). 'The Plight of rural women: alternatives for action'. *International Labour Review* 119, 4, 425–438.

Ashby, J. (1981). New models for agricultural research and extension: the need to integrate women. In *Invisible Farmers: Women and the Crisis in Agriculture*, pp 32–56 , pp 144–186, (Ed. B. Lewis), Washington DC: USAID.

Blumberg, R. (1981) Rural women in development. In *Women and World Change*, pp 32–56, (Eds. N. Black and A. B. Cottrell), Beverly Hills, Ca., Sage.

Development Forum (1987). Vol. XV No. 3 *UN Directorate for Economic and Social Information*/DPI UN University.

Dixon, R. (1982). Women in agriculture: counting the labor force in developing countries. *Population and Development Review* 8, 3, 539–666.

Gabriel, T. (1991). *The Human Factor in Rural Development*. London: Belhaven Press, Pinter Publishers.

Gabriel, T. (1990). Pest management, women and rural extension. *Trop. Pest Manage*. 36, 173–176.

Jiggins, J. (1983). *Agricultural Extension and Planning for Rural Women*. Report for Expert Consultation on Women in Food Production, Rome: Food and Agriculture Organisation of the United Nations.

Jiggins, J. (1986). *Gender-Related Impacts and the Work of the International Agricultural Research Centres*. Washington DC: World Bank Consultative Group in International Agricultural Research, Study Paper 17.

Newman, K. (1977). Women and law: Land tenure in Africa. In *Women and World Change*, pp 29–38, (Eds. N. Black and A. B. Cottrell), Beverly Hills. Ca., Sage.

Palmer, I. (1977). Rural women and the basic needs approach to development. *International Labour Review*, 115, 1, 97–107.

Purvis, B. M. (1986). *Information for Women in Agricultural Extension in ACP Countries*. Wageningen: Technical Centre for Agricultural and Rural Cooperation, Study Report.

Rogers, B. (1980). *The Domestication of Women*. London: Tavistock .

Weidemann, C. J. (1987). Designing agricultural extension for women farmers in developing countries. In *Agricultural Extension Worldwide: Issues, Practices and Emerging Priorities*, pp 176–198, (Eds. W. M. Rivera and S. G. Schram), London: Croom Helm .

The Current Status and Role of Networking in Pest Management in Africa

Yaya A. Olaniran

The International Centre of Insect Physiology and Ecology (ICIPE),
P. O. Box 30772, Nairobi, Kenya

SUMMARY

Research networks exist all over the world. Some are commodity oriented whilst others are discipline or subject inclined or multi-disciplinary. Their functional efficiencies vary considerably as their objectives. A well-organized and properly focused network is cost-effective as it avoids the establishment of new bureaucracy and it also has the advantage of avoiding duplication of research activities and encourages information exchange.

Pest management in Africa is complicated by inadequate trained manpower, communication difficulties as well as shortage of efficient facilities. Other impediments include language barriers (English, French, Portuguese etc.) amongst affected countries; logistical problems (e.g. immobility of scientists across borders) and ineffective agricultural extension systems of most African countries as well as the lack of sufficient resources to accomplish profitable management of pests. The diversity of both crops and pests complicates the problem. In spite of the problems deliberate efforts are made to use various techniques to manage pests and thereby ensure food sufficiency. The ICIPE experience is elucidated with lessons learnt for incorporation into future operations.

INTRODUCTION

Common insect pest problems plaguing Eastern and Southern African countries and determination to stem the menace of crop destruction in the field have currently motivated 12 countries: Burundi, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Somalia, Sudan, Tanzania, Uganda, Zambia and Zimbabwe to form the Regional Pest Management Research and Development Network (PESTNET) with ICIPE being the prime mover. The initial concept was to operate the network as equal partners between ICIPE and each PESTNET member country. This could not be achieved largely because of a wide and varied but insufficient number of available trained entomologists in the different countries. Research priorities of each country within the network too are different. For example, mission-oriented surveys showed clearly the different crop priorities as: maize/sorghum; maize; banana/bean combination for Somalia, Zambia and Rwanda respectively. The corresponding pest priorities of the three countries were: (i) stem borers (e.g. *Chilo partellus, Busseola fusca*); (ii) *Cicadulina* sp which causes maize streak virus disease: and (iii) banana weevils/nematodes complex.

Trained manpower was seen to be inadequate in terms of number and quality in some member countries. Hence ICIPE has trained or is training a total of four nationals from three countries at the Ph.D. level in the African Regional Postgraduate Programme in Insect Science (ARPPIS). The scholars are on completion of their training designated to take over the headship of research teams in their respective countries. The advantage is that in administrative terms a national can solve local problems more easily and can influence the national government to support the network positively and to provide operational or logistical support whilst the scientist is motivated and supported by the ICIPE, through provision of intellectual contacts with peers, and where necessary research equipment. Strategies of pest management include IPM tactics, detection, quarantine and control. The sustainability of adopted pest management strategies in developing African countries in terms of cost, pest resistance to control methods and negative impacts to the environment and human health is critical. It is for these reasons that ICIPE research work has emphasised no use or minimal use of pesticides.

Primary constraints to effective pest management in Africa such as socio-economic, institutional and policy issues invariably have no direct bearing on the quality of the science. It is therefore imperative to correct the mutual participation of all the participants i.e. ministry officials, farmers, social scientists and natural scientists.

Selected research objectives must be constraint-driven. A strategy developed to address constraints comprised a blend between traditional knowledge and modern science.

Two types of known pest management tactics have been employed namely:

(a) Those that demand a high degree of farmer involvement (e.g. cultural practices like intercropping, weeding, and use of pesticides);

(b) Those that generally need minimal farmer involvement (e.g. classical biological control; host plant resistance).

THE ICIPE EXPERIENCE OF PEST MANAGEMENT NETWORK

The objectives of the African Regional Pest Management Research and Development Network (PESTNET) are to improve food security of developing countries in the tropics and sub-tropics, especially in Africa. These are to be achieved by improving the control of insect pests of crops, and vectors of human and animal disease through the development and dissemination of integrated pest management techniques by a network of concerned member states. In order to achieve this goal PESTNET has the following objectives:

(a) The generation, development and dissemination of technology for the control of designated insects and disease vectors;

(b) The establishment of an efficient data handling system;

(c) The strengthening of the national scientific leadership in insect science of member countries through education and training in integrated pest management methodologies.

PESTNET adopted a more interactive approach to networking rather than the "hub and spokes" model as far as research activities are concerned. However, the "hub and spokes" model is being developed for the information sharing aspect under the Pest Management Documentation Information Systems Services (PMDISS).

The objectives of PMDISS are to develop a data handling network that will satisfy the needs of the network for the gathering, collation, retrieval and dissemination of scientific information. The consequent outputs expected from the PMDISS are:

(a) To establish a centre dealing with documentation and information relating to insect pest and vector management that will serve the information needs of PESTNET and other users in the developing world especially Africa;

(b) To develop and consolidate an efficient information exchange and document delivery capacity between the relevant national institutions of the network countries and the ICIPE;

(c) To develop a computerised database and an extensive collection of literature hard copy with special emphasis on grey literature;

(d) To collaborate and cooperate with other organisations in the exchange of information.

The interactive model was chosen for research activities because it satisfies part of the mandate of ICIPE to strengthen national agricultural research systems (NARS) as well as to transfer validated technologies to the farmers. Experience has shown that simplicity and low-cost of technology is an asset e.g. trapping of tsetse with NGU trap. To get to the stage of trapping tsetse, several stages such as basic research, applied research and technology development had taken place. For basic research, the study of the sensory-physiology of tsetse (e.g. attraction to blue colour), responses to external stimulus (e.g. odour from wild and domesticated animals) were studied. In addition, the ecology and biology of the tsetse and its response to odour-bait were then carefully related to the trap technology in an applied research sense which took into account cooperation with the ultimate user community. Another example is the trapping of sandfly by means of polythene coated with castor oil. In crop research development, the use of the traditional method of intercropping or varying planting dates to markedly reduce insect damage and thereby increase crop yield is more interesting. Scientific explanation here is being adduced following careful observations and monitoring of the insects activities.

TYPES OF NETWORK MOTIVES

Two of three well-known network motives have been applied to-date in the ICIPE integrated pest management strategies. These are:

(a) Specialist field of interest which is all aspects of insect science basically for information exchange and sharing of research work.

(b) Exploration of alternative models of development, hence charting new paths and strategies. However, the third type where multi-disciplinary experts are brought together is currently gaining ground. The experts include: biological scientists, social scientists, farming communities as well as extension officers, amongst others.

The traditional interactive technology developments illustrated below (Fig. 1) have been modified to ensure increased efficiency and close collaboration with resultant improvement. Figure 2 offers a diagram of the functional relationship between the ICIPE and the Network activities.

***Fig. 1.* Interactive technology development**

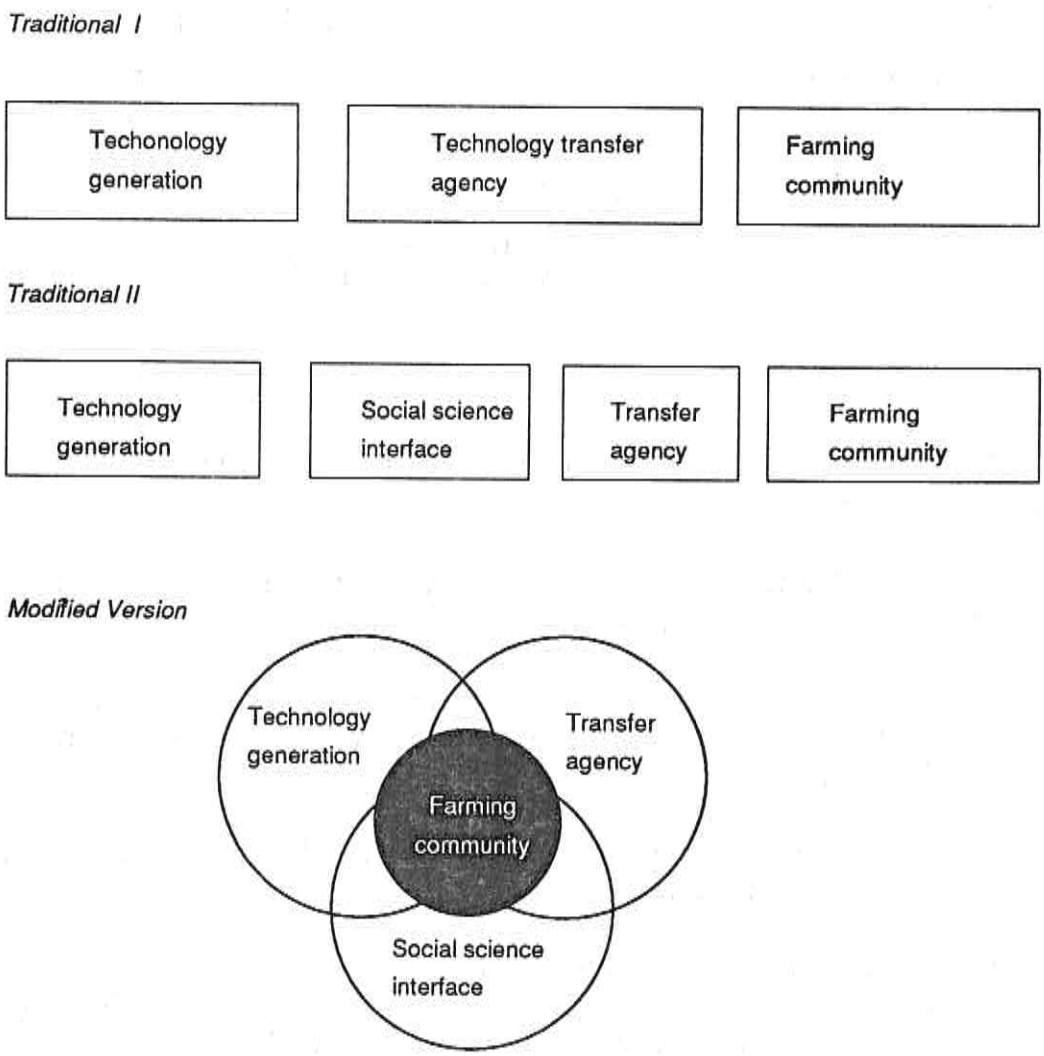
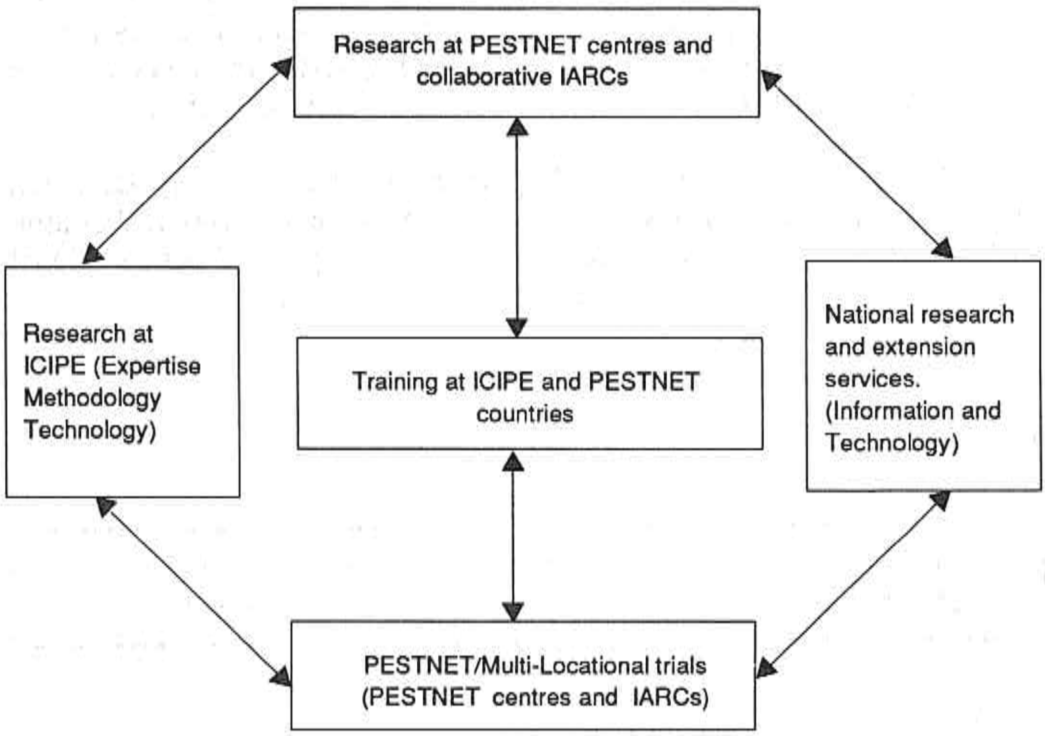


***Fig. 2.* Functional relationships between ICIPE and national programmes in PESTNET**



PROBLEMS ENCOUNTERED IN PEST MANAGEMENT NETWORKING

In general, problems confronting pest management specialists in Africa affect the efficiency of networking. These include:

(a) Budgetary constraints which prevent the free flow of information as provided by specialised laboratories and libraries, with lack of computer facilities.

(b) Inaccessibility to well-equipped institutional library or information and documentation facilities.

(c) Insufficient and/or outdated modes of communication with pest management specialists in the developed countries; and the difficulty in translation of texts from one language to another.

PESTNET ACTIVITIES IN MEMBER-COUNTRIES

Country		Project of interest	Objective
1. Somalia	(i)	Study of predators and parasitoids of stem borers	Manage stem borers of maize and sorghum especially *Chilo partellus*
	(ii)	Facilitating training of various cadres of (a) Ph.D. insect science (b) Mass rearing (c) Computer handling	Strengthen national capacity building, establish sustainable IPM strategies for use by farmers. Identify MSVD resistant cultivars, strengthen national capacity-building
2. Zambia	(i)	Evaluation of commercial maize resistant to maize streak virus disease (MSVD) using *Cicadulina* sp.	Establish sustainable environmentally safe IPM strategies for farmers
	(ii)	As (ii) above	
3. Rwanda	(i)	Study of banana/bean intercrop complex with respect to banana weevils/ nematode interactions	Manage the pests using environmentally safe strategies
	(ii)	Facilitating training of a national to Ph.D. level	Improve national manpower in insect science
4. Tanzania	(i)	Collection of information on banana/bean intercrop complex with respect to banana weevil/nematode interactions	Exchange and sharing of information

☞

Country		Project of interest	Objective
5. Kenya	(i)	Study of the management of stem borers at different ecological zones e.g. intercropping of maize with legumes	Introduction of new improved IPM strategies to farmers
	(ii)	Establishment at ICIPE of data bank for pest management information service systems (PMDISS)	Information collection and dissemination
6. Uganda	(i)	PMDISS Locus	Information collection and sharing
7. Burundi 8. Mozambique 9. Zimbabwe 10. Malawi 11. Sudan	}	Consultative and interactive meetings and workshops	Exchange and sharing of experience
12. Ethiopia		Consultative and interactive meetings and workshops plus tsetse trapping technology development	Exchange and sharing of experience

LESSONS LEARNT FROM PHASE I OF PESTNET

To-date ICIPE Pest Management Network has not achieved fully the hopes and aspirations expected, largely because of unequal levels of manpower development among member states. Consequently, a period of consolidation was established when all member states participated fully in the evaluation of the project with careful analysis of the weaknesses that emerged from the implementation of the first phase. IPM strategies are more meaningful and beneficial when developed and especially validated in close cooperation and collaboration with farmers contributing their traditional knowledge of crop and livestock improvement methods. It was agreed that the next phase would be designed to emphasise this aspect of effective translation of IPM strategies into practice and therefore better productivity.

Another clear lesson emanating from phase one is that deliberate efforts must be made to keep the objectives strictly focused. Otherwise other peripheral issues will become dominant. Finally on the question of the usual criticism levelled against networks that the personnel lack appropriate management skills, efforts are being made in ICIPE to employ staff with experience and also routinely train staff once deficiencies are observed. This calls for close monitoring and critical analyses of procedures and output.

ULTIMATE ACHIEVEMENTS OF ICIPE'S NETWORK

The ultimate achievements would include: firstly the enhancement of food production by farmers and herdsmen based on properly planned, well-co-ordinated and functional network of pest management. Secondly, the maintenance of a series of well-focused scientific networks which are chain-linked with periodic evaluation of methodologies and achievements that ensures participatory approach founded on mutual respect and understanding. Thirdly, facilitating successful interactions of participants at various meetings with the sole aim of implementing strategic follow-up actions to issues of improvements of crops and livestocks.

All pest management network participants must actively facilitate the implementation of policy and research of Integrated Pest Management that are environmentally, economically, and socially sustainable. It is our hope that a successfully established PMDISS will alleviate some of the problems mentioned but will also ensure stronger links to be fostered with National Research Systems in Eastern and Southern Africa and expansion to other parts of Africa.

Products versus Techniques in Community-Based Pest Management

David Dent

School of Pure & Applied Biology
University of Wales, College of Cardiff
P. O. Box 915, Cardiff CF1 3TL

SUMMARY

This paper considers the emphasis in research that is placed on developing pest control "products" rather than "techniques" for control, the reasons for this and its implications for community-based pest management.

Data are presented that indicate a preponderance of research carried out on pesticides, pest resistance and biological control relative to cultural control. In the light of these data the role of products and techniques are considered for each of the above control options. A bias in favour of research on pest control products is clearly evident. The reasons for this are presented from the perspective of the agro-industry, the scientists and the funding agencies.

The implications for the bias towards development of pest control products are considered in relation to the needs for community-based pest management. An argument is put forward for a more balanced approach to pest management utilising both products and techniques.

INTRODUCTION

There are many definitions of IPM but the one I prefer is a modification of that proposed by Smith & Reynolds (1966) that states, "in the socio-economic context of farming systems, the associated environment and of the population dynamics of the pest species, utilises all suitable techniques and products in as compatible a manner as possible, and maintains the pest population levels below those causing economic injury". The relative merits of this and other definitions could be debated for the rest of the day but even then we would still disagree as to the precise wording and emphasis to be used. One point on which I'm sure we would all agree, however, is that the essential ingredient of IPM is the integration of a number of different control measures, each contributing something to pest reduction in order to achieve an overall acceptable level of control. I think we might also agree, even if we didn't include it in our definition, that IPM programmes should be sustainable.

It is my contention in this presentation that certain types of control measures, that I refer to as products, are considered more in research than others that I refer to as techniques; all to the detriment of community-based pest management.

A product may be defined as a thing or substance (which may be living organisms, chemicals, plant material) that is usually manufactured, produced, formulated or packed for the purpose of sale. They are essentially purchased as off-farm inputs and are characterised by their commercial value, their general application and, for many, their broad spectrum effects. A technique by contrast, is a form of procedure, skill or method that may be utilised by the farmer from available on-farm resources. They are often based in principle on traditional agronomic and husbandry practices and tend to be specific at least to the level of the cropping system.

I believe, and I hope to convince you of my argument, that greater emphasis is placed on the development of control measures based on products than on techniques and that this creates a strategic imbalance in pest management that prevents sustainability and causes problems for the farmer. I want then, in presenting this case to consider four things:

(i) what evidence I have in support of my contention
(ii) why should such a bias occur
(iii) what are its implications and
(iv) how can the situation be remedied?

THE EVIDENCE

Firstly what evidence is there to support the idea that more research is carried out on products than on techniques. To start let us consider where each of the control measures used in pest management fit with regards to being products or techniques.

There are generally recognised to be five established approaches to pest control: (i) pesticides (ii) biological control (iii) pest resistance (iv) cultural control and (v) interference methods.

Pesticides include herbicides, insecticides, fungicides, microbials, insect growth regulators. Biological control; classical introductions, augmentative releases and conservation of natural enemies. Pest resistance; antibiosis, antixenosis and tolerance. Whereas cultural control includes; intercropping/ polycultures, alley cropping, tillage techniques, planting time, plant spacing, habitat modification and mulching, to name but a few. Interference methods include the sterile insect technique, pheromones (disruptants) and genetic engineering.

All of these control measures can be categorised as either products or techniques, or somewhere in between, by the following scheme (Fig.1). In some instances it is difficult to make a clear distinction because as circumstances vary a control measure may move between being classed as a technique or a product. Also, some control measures have only some of the characteristics of a product or technique. Hence, the situation is depicted as a continuum. Pesticides are clearly products, as are semiochemicals, insecticides, microbials and insect growth regulators. Cultural control methods are obviously all easily classifiable as techniques. Within biological control augmentative releases of natural enemies classify, at least in my opinion, as products, e.g. the purchase by growers of *Encarsia* for control of whitefly in glasshouses. Conservation of natural enemies, is definitely a technique. Introduction of exotic natural enemies, however, falls somewhere between the two; they are generally applicable but they are not usually for sale.

Host-plant resistance presents an interesting situation. In traditional farming, farmers keep seed from their crop that they wish to use for sowing next season. Seed selected in this way, over many generations produces crops adapted to local conditions and pest problems. This classes host-plant resistance as a technique.

In the market economy, however, the farmer purchases the seeds for sowing at the start of each season. The plants are bred elsewhere and the seed is selected from plants having desirable traits, not necessarily locally adapted characteristics, however, but for generally suitable characteristics. The extreme example being hybrid plants, where seed is infertile so farmers have to purchase seed each new season. In general host-plant resistance, i.e. the

Fig. 1. **Pest control products and techniques that are potentially available for community-based pest management**

Products	◄——— Continuum ———►	Techniques
Pesticides Herbicides Fungicides Microbial Insect growth regulators		
Semiochemicals		
High yielding hybrids	Host plant resistance	Traditional farming selection of seeds from crop
Augmentation of natural enemies	Biological control	Conservation of natural enemies
		Cultural control Intercropping Plant spacing Planting date Tillage practices Habitat modification

development of resistant plants, errs very much towards the products side of the continuum.

One point that is particularly interesting in relation to the biological control and especially to the host-plant resistance situation is that there are two control measures that were traditionally techniques, but with what we advocate today, they have been taken away from the control of the farmer and are now being developed as products. For example, I know of no programme advocating and encouraging farmers to identify and select seed from pest resistant plants within their own crops for use in following seasons.

Now I want to consider what evidence there is to support the idea that greater emphasis is placed on developing products rather than techniques in IPM. In the first instance I want to turn to a small piece of circumstantial evidence. That is, that governments will fund research and development of all the categories of pest control, either directly through its own research institutes or indirectly through grants to its universities etc. whereas industry have to-date, only been interested in carrying out research and development of products.

There are commercial chemical companies, companies producing microbial pesticides, insect growth regulators, commercial companies founded on selling pheromones and even augmentation of natural enemies. More recently chemical companies are purchasing into seed companies as the development and possibilities for genetically engineered plants gathers momentum. But where are the companies interested in intercropping, plant spacing, tillage practices and habitat modification? Of course, there are none!

On this basis alone, we can be sure that more money and effort is being ploughed into products rather than techniques.

But what other evidence is there? Since the number of publications produced is a fairly good indicator of the research effort put into any subject, it seemed reasonable that a search of the CAB Abstracts Database, with appropriate key-words, should provide an indication of the relative numbers of papers published on the different subjects. An on-line computer search of the database was carried out for the years 1979–1990 using the key words in Table 1.

***Table 1.* The number of publications (1979–1990) dealing with different control options in pest management. Obtained from on-line computer search of the CAB Abstracts Database**

Subject key word(s)	Number of publications
Pesticides	30,769
Herbicides	8736
Insecticides	7500
Fungicides	5186
Biological control or biological control agents	10,434
Pest and disease resistance	9013
Pheromones	2568
Cultural control or cultural methods	1728
Sterile insect technique or sterile male technique	56

Even in these modern times when the philosophy of IPM is well entrenched, there is still a very large amount of work carried out on the different aspects of pesticides—as a group more than any other category of pest control measure. As we go down the list in Table 1, it is evident that the number of papers published in each category decreases down to 1728 for cultural control methods and 56 for sterile insect technique. It would not be sensible to place too much emphasis on the absolute numbers involved in each case since I am sure everyone is aware of the problems with such data. For instance, when first considering pheromones I put in the key word "semiochemical", since this is the broader definition of the class of control measure. When I did so the database informed me there were only 90 papers published on semiochemicals during the last 11 years — or rather there were only 90 papers published that used semiochemicals as a key word to describe their paper, whereas the key word pheromones produced 2568. Hence, you can see that the result you obtain is entirely dependent on the key words you use. I have tried to be as objective as possible and have in each case used the key words that provide the highest number of publications, any other criteria would have led to an unacceptable level of subjective assessment. It is the overall trend that needs to be stressed here, the relative rather than the absolute figures. Despite the drawbacks of such data I am confident that fewer papers are published on control methods relating to techniques than to products. More work is being carried out on products than on research into techniques.

THE REASONS FOR THE PRODUCT BIAS

The reasons for the product bias towards products can be considered from the perspectives of (i) the agro-industry, (ii) the scientist and (iii) the funding agencies.

THE AGRO-INDUSTRY

The agro-industry will be looking to develop technologies that have a number of these characteristics in Table 2. If a control measure does not have a large number of these characteristics then the agro-industry are unlikely to show much interest. Since most of these characteristics refer to products rather than techniques, it is easy to see why commercial companies do not fund research into techniques.

***Table 2.* The role of the agro-industry**

For the agro-industry to adopt new pest control technology, it must have a number of the following characteristics:

1.	Commercial value
2.	Broad spectrum effects
3.	Generally applicable
4.	Easily marketable
5.	High performance
6.	Reliable
7.	Visibly effective
8.	Low hazard and/or toxicity to humans

THE SCIENTIST

Scientists also have a role in promoting the bias towards development of products rather than techniques. Scientists are dependent on funding for their work hence, the type of work carried out will to some extent be influenced by policy decisions made by administrative and funding agencies. Scientists will be channelled into areas of research where there is money available. Every scientist wants to be at the driving edge of their science, that is where the interest is, that is where the glamour and prestige lie. Such things are, however, rarely associated with techniques such as planting date and planting density experiments; the type of work involved in cultural control research. There are no dramatic solutions to major pest problems there— or am I too cynical?

It often seems to be the case that the training of scientists involves too much specialisation—we get too tied to a particular subject so that scientists become removed from the practical realities of life. It is much easier for a scientist to look at problems in isolation within their own narrow specialisation, when dealing with products than with techniques. When dealing with techniques, a scientist has to be in the field, in the thick of it, working with farmers, socio-economists, agronomists and anthropologists. Too few scientists are able to cope with such things. We need more scientists trained with the skills for interdisciplinary research.The role of scientists in product development can then perhaps best be summarised by the five headings in Table 3.

Table 3. The role of the scientist

Scientists prefer to be involved in the development of new pest control technology that provides:
1. Adequate funding
2. Opportunities for pioneering research
3. Prestige
4. Problems within their own specialist subjects
5. Dramatic solutions to major pest problems

FUNDING AGENCIES

Funding agencies have a great responsibility for influencing the direction of research. Hence, it is important that we look to this group for reasons why pest control tends to emphasise products rather than techniques. Funding agencies will tend to support projects that have the following criteria (Table 4):

Table 4. The role of funding agencies

Funding agencies prefer to support projects involved in pest control that:
1. Match their own priorities and budgets
2. Provide maximum impact for minimum funding
3. Involve the latest technologies
4. Provide a high profile for funding agency

(i) A project must match their own priorities and budgets—obviously many constraints are placed on agencies and they can only supply a limited amount of money coincident with their own objectives.

(ii) A project should provide maximum impact for minimal funding. Since there are always limited resources, agencies will want to use their money to achieve as much as possible, and because I would suggest, the most dramatic effects occur with products, these are more likely to be funded.

(iii) Project should involve the latest technologies, everyone wants progress, the furthering of science, hence new potential products take priority funding over techniques, many of which just seem like "old hat".

(iv) Projects should provide a suitably high profile for the funding agency. Funding agencies live within the world of politics and commerce and so they have to be seen to be doing what is politicallly expedient. In the present climate, at least in the UK, that means developing products for industry.

Given all of these points it is easy to see why funding agencies are very much more likely to support products than techniques. Overall, if you consider the roles of the agro-industry, the scientist and the funding agencies, then there is little wonder why products seem to predominate in the general scheme of pest management.

But why does this matter? What are the implications for such a bias in community-based pest management.

THE IMPLICATIONS

There are a number of problems associated with the use of products:

(i) Their use is totally dependent on their availability. The product must be present in the retailers at the appropriate time at a suitable cost. The cost of the product will affect its availability to the farmer. Availability may then be dependent on the availability of credit, the maintenance of subsidies by government or aid programmes or the capital resources of the farmer; all of which may fluctuate within and between seasons.

The product must be available at the time at which the farmer requires it. This does not always happen—all sorts of problems can occur that affect the timely arrival and distribution of products within a country, especially where the product has to be imported.

(ii) The product must be reliable, the necessary infra-structures must be in place to ensure that products are not subject to adulteration by packaging and distribution companies. A problem that was highlighted by the work of Grace Goodell in the Philippines where it was shown that 40% of seed sold as resistant cultivars were in fact susceptible. Similarly 70% of the bottles of pesticides purchased from local retailers contained chemicals adulterated to more than twice the acceptable standard of deviation. We would be naive indeed to believe that this was a problem confined only to the Philippines.

Given these problems, it would quite naturally seem unwise to place all your "eggs in one basket" and deal only with the development of products. Yet it seems that this is largely what we are doing. But doing so leaves the farmer and whole communities locked into a pest control system that has no fail-safe mechanism. What is actually required is a balanced strategy that allows farmers the optimal use of products but provides them with a fall-back position should these products fail them, for the reasons given above. Pest management techniques can provide such a fall-back position, but if they are to do so then more effort needs to be directed towards their development. More effort is needed to redress the imbalance that exists in the emphasis in research placed on products relative to techniques.

However, given the reasons I stated earlier for why this emphasis exists, it would perhaps seem an impossible task to reverse the trend.

Difficult yes —impossible no!

A SOLUTION

Well, firstly, no-one can seriously ask or expect the agro-industry to stop developing products. Product development, marketing and sales, is their business and that is the way it will always be and it should be. We cannot function in IPM without it. But IPM should not be based on products alone! The development of techniques in pest management needs to be encouraged through influencing scientists and funding agencies.

At present there tends to be either an emphasis on pest control for a particular pest or the development of particular classes of control measure. Such approaches mean that pest control is viewed in isolation of the cropping system in which it is to operate, a situation in which it is easy to neglect the unglamorous role that techniques have to play. If, however, research is carried out at the systems level of the crop and the objective is to produce an IPM programme, then techniques of cultural control automatically have a place. Products are developed in association with techniques.

When dealing with pest control at the level of IPM and cropping systems it is easy to see the balance that is required and techniques are automatically included as a consequence of this. A good example of this shown here at this meeting has been the work of Professor Saxena and his team, another is the programme at Cardiff in which I am technical manager, and which is co-ordinated by Peter Haskell. This is an EEC funded programme of research for development of IPM in European olives. This is a programme of research between four countries and 11 different institutes, but despite this we have a common objective of developing an IPM programme. We work as a team organising protocols and schedules of work between disciplines. Within this context we quite readily integrate the work of microbiologists, chemists, modellers, entomologists and industry. Within this context, techniques naturally take their place alongside products, because we are dealing with the whole system and when dealing with the whole system it is obvious that a balance is rèquired between the two approaches.

I am convinced that if such studies as ours at Cardiff and the work at ICIPE can be shown to be effective, then general recognition of the value of the systems approach will encourage funding agencies to adopt policies to promote such research. In doing so we will iron out the imbalances between use of products and techniques in pest management and provide farming communities with pest management programmes that are both productive and sustainable.

ACKNOWLEDGEMENTS

I would like to thank Pauline Richards of UWCC Science Library for carrying out the on-line computer search of the CAB Abstracts Database, and Rosy Allcott for typing the manuscript and producing figures and tables for the presentation.

REFERENCES

Goodell, G. (1984). Challenges to international pest management research and extension in the Third World: do we really want IPM to work? *Bull. Entomol. Soc. America* 30, 18–26.

Goodell, G. (1989). Social science input into IPM. *Trop. Pest Manage.* 35 , 252–253.

Smith, R. F. and H. T. Reynolds (1966). Principles, definitions and scope of integrated pest control. *Proceedings of FAO (United Nations Food & Agriculture Organisation) Symposium on Integrated Pest Control* 1, 11– 17.

Pesticides in Kenya

G. N. Kibata

Crop Protection Coordinator
Kenya Agricultural Research Institute,
P. O. Box 14733, Nairobi, Kenya

SUMMARY

While the global perception of pesticides is undergoing drastic changes, it is recognised that they have made and will continue to make an enormous contribution to food production as well as to human health and welfare for a long period in the future.

The achievements made in Kenya as regards crop and livestock production as well as human health owe a great deal to the use of pesticides in spite of the increasing concern about their widespread misuse. Vector-borne diseases have debilitated and taken a heavy toll of livestock and human lives prior to the advent of pesticides in Kenya, as in most parts of tropical Africa. It is also documented that the use of pesticides has reduced both pre and post harvest crop losses.

Most of the pesticides used in Kenya are synthetic chemicals which are imported from industrialised countries. It is estimated that it costs the country approximately K£ 32–42 million in foreign exchange to import the pesticides annually; the various types include insecticides, acaricides, herbicides, fungicides and rodenticides.

Since 1982 the government of Kenya has instituted a legislation and management scheme for pesticides in recognition of their important role in the economy. This paper discusses the various issues relating to the use of pesticides and the changing perception of the chemicals in the country.

INTRODUCTION

As in many developing countries of tropical Africa, Kenya is largely dependent on crop and livestock production to feed her fast increasing human population as well as to sustain a viable cash economy. Vast areas of the country are arid or semi-arid and are barely productive under the prevailing rainfed crop production. The scourge of numerous vector-borne livestock and human diseases further constrains the productivity of the country. The legion of crop pests (insects, mites, bacteria, fungi, nematodes, weeds and vertebrates) cause substantial losses in quantity and quality of agricultural produce. Although crop losses due to pests are poorly documented, small losses which often go unnoticed by the farmer add up to an enormous national loss. Total losses can be best exemplified by outbreaks of armyworms on young crops of maize, the recent unprecedented destruction of stored maize by the larger grain borer or epidemics of plant diseases such as late blight on European potatoes. The depression of crop yields due to weed competition and the amount of farmers' time and resources which is devoted to weeding further emphasise the importance of this category of crop pests.

There has been much adverse publicity in some countries about misuse, overuse and even stoppage of use of pesticides. Yet they remain the most powerful and effective tool which we can promptly bring to bear upon threatening pest populations. Rational use of pesticides in combination with other pest control tactics should therefore constitute a sound pest management strategy or what is often referred to as the Integrated Pest Management (IPM).

PESTICIDES USAGE IN KENYA

The bulk of pesticides which are used in Kenya are imported from various manufacturers in Europe, the United States and Japan. Most of them are offered as finished ready-to-use products while a few of the pesticides are formulated locally from their technical grade concentrates. Marketing of pesticides is undertaken by agrochemical companies who may be principals or subsidiaries of the manufacturers overseas with a distribution network of wholesalers and retailer outlets. From various statistics it is estimated that the pesticides market fluctuates between K£ 32–42 million annually (Pest Control Products Board 1986–1990; Needham, 1989; Landell Mills, 1980, 1989). (Tables 1, 2, 3, 4).

Table 1. **Importation of different groups of pesticides into Kenya (1986 –1990) Value (C + F) — million Kshs**

Year	Insecticides and acaricides	Herbicides	Fungicides	Others	Total
1990	260.3	159.4	169.2	55.6	644.5
1989	208.1	154.2	328.8	30.7	721.8
1988	134.9	121.3	281.3	42.6	580.1
1987	182.3	173.4	357.3	28.1	741.1
1986	134.9	121.3	281.3	42.6	580.1
Mean	184.1	145.92	283.58	39.92	653.52

Source: Pest Control Products Board, Nairobi, Kenya.

Table 2. **Pesticides imported into Kenya (1986–1990) in % total value**

Year	Insecticides/ acaricides	Herbicides	Fungicides	Others
1990	40.4	24.7	26.3	8.6
1989	28.9	21.4	45.5	4.3
1988	24.0	21.9	49.8	4.3
1987	24.6	23.4	48.2	3.8
1986	23.2	20.9	48.6	7.3

Source: Pest Control Products Board, Nairobi, Kenya.

Table 3. **Importation of different groups of pesticides into Kenya (1986 – 1990) Quantity — tonnes**

Year	Insecticides and acaricides	Herbicides	Fungicides	Others	Total
1990	1572	1134	1330	857	4893
1989	1571	1148	4327	665	7711
1988	1089	2108	4259	801	8257
1987	1206	1311	7157	697	10,371
1986	1076	1129	6584	808	9597
Mean	1302.8	1366	4731.4	765.5	8165.8

Source: Pest Control Products Board, Nairobi, Kenya

***Table 4.* The market value of pesticides by crop (1988) Commercial sectors (in order of value)**

		Market 1988 (Wholesale level) Sterling £000
1.	Coffee fungicide— CBD	6,240
2.	Coffee fungicides — Leaf rust	2,700
3.	Coffee insecticides	2,500
4.	Coffee herbicides	2,000
5.	Wheat/barley herbicides	1,500
6.	Horticulture insecticides	1,500
7.	Potato fungicides	1,100
8.	Cotton insecticides/acaricides	1,000
9.	Tea herbicides	850
10.	Wheat/barley fungicides	700
11.	Horticultural fungicides	700
12.	Maize herbicides	680
13.	Maize insecticides	500
14.	Sugarcane herbicides	490
15.	Foliar feeds	400
16.	Sisal herbicides	390
17.	Pineapple nematicides	300
18.	Maize seed dressing	150
19.	Wheat/barley insecticides	110
20.	Tobacco insecticides	130
21.	Tobacco nematicides	120
22.	Wheat/barley insecticides	110
23.	Tsetse fly control	100
24.	Horticultural herbicides	80
25.	Tobacco fungicides	80
26.	Pineapple root mealy bug	60
27.	Pineapple herbicides	60
28.	Tea acaricides	30
29.	Sunflower/rape herbicides	30
30.	Rice insecticides	30
31.	Sugarcane seed dressing	25
32.	Pyrethrum insecticides	20
33.	Cotton seed dressing	20
Sub-total		**24,945**
Others		**2,155**
Grand total		**27,000**

Source: Needham Enterprises Ltd., Nairobi, Kenya

The broad categories of pesticides for target uses include:

Crop pests	—	Insecticides + miticides fungicides herbicides + plant growth regulators nematicides rodenticides avicides
Animal health	—	acaricides insecticides
Public health	—	insecticides rodenticides molluscides

Crop protection consumes over 90% of the pesticides used in the country. Under this category fungicides hold the lead position followed by insecticides and herbicides.

Pesticides usage is mainly applicable to the large scale cash crop production rather than the smallholder food crop or subsistence farming. The smallholder sector, is however, currently undergoing fast changes towards cash crop economy, especially in horticultural crops production, resulting in higher use and demand for agrochemicals including pesticides. The smallholder sector represented 83.5% of a total crop hectarage of 2,366,000 hectares (Ministry of Agriculture statistics 1988). This sector is expected to grow steadily over the next few years as large farms are further sub-divided.

Coffee is the leading crop in the use of pesticides followed by major cereals (wheat and barley) obviously related to better returns on investment. Horticulture, which is a steadily growing industry, is also a major consumer of numerous pesticides although the actual quantities by product may be fairly small. The market value of pesticides sold for various crops would generally indicate the trend of pesticide usage in Kenya (Needham, 1989). The value of the acaricides market during the same period was estimated at Kshs. 90.5 million for the following major products (Annual reports, provincial and district veterinary officers, 1988).

Common name	**Trade names**
Chlorfenvinphos	Steladone
	Supadip DFF
	Supona
Dioxathion	Delnav DFF
Chlorfenvinphos +	Supamix DFF
Quintiofos	Bacdip DFF
Amitraz	Triatix

The critical decision as to when to use a pesticide has been given appropriate consideration elsewhere and need not be discussed further here (Kiss, 1985). It should, however, be noted that the farmer's knowledge of pesticides is limited except for some cash crops where the production package often provides some guidance on crop protection.

Most of the information on the use of pesticides is therefore often gained through exchange of experiences within the farming community or through the agrochemical industry and their marketing outlets. Whereas research organisations or the regulatory bodies such as the Pest Control Products Board will have up to date information on pesticides, that knowledge is not effectively disseminated to the farmers either through the existing extension system or the few commodity handbooks.

There is, therefore, a real need to develop a training programme for both the extension service and farmers with the specific objective of transferring available knowledge on pesticides to these sectors.

MISUSE OF PESTICIDES

Misuse of pesticides is a global problem but is more accentuated in developing countries where resources and technology are major contributory factors. To achieve useful biological performance adequate dose or quantity of the appropriate pesticide must be delivered to the target. The choice of the correct pesticide and the application method are therefore critical issues in determining the biological efficacy as well as the environmental impact likely to arise from pesticides usage.

Farmers in Kenya have had limited options as to which pesticides to use and the choice of application equipment. The vast majority of pesticides offered in the market are commodity products with broad spectrum activity on both pests as well as their natural enemies. Pesticides with selective activity on target pests are extremely few and it is therefore a common practice to find farmers using a single or closely related product for several pest problems. Herbicides are however an exception in this regard as most of them are selective in activity as well as crop tolerance. Pesticide formulations which are available to farmers are also limited and include liquids, powders, dusts and granules. These formulations are applied through a variety of high, low and ultra low volume spray equipment which include knapsacks, tractor booms, mist blowers, aerial and ULV sprayers using spinning discs and micronairs. The pesticide delivery systems are both inefficient, unsafe to the user and least target oriented, resulting in waste of pesticides and excessive contamination of the environment. In most cases the amounts of pesticides delivered to the target crop is far in excess of the dose required for biological activity which often results in unacceptable pesticides residues on produce.

During on farm surveys it has often been noted that the timing of pesticide application is also a major component in the misuse of the chemicals. Safe and correct storage, handling and mixing of pesticides and maintenance of application equipments are further aspects which are poorly developed and result in misuse of the available products.

DISPOSAL OF PESTICIDES

In spite of the limited resources for purchasing pesticides the country is faced with an intractable problem of large stocks of expired or substandard pesticides which were either acquired through commodity aid programmes or unplanned importations. To confound the issue further, Kenya has yet to develop a policy as regards the disposal of chemicals and empty containers. Technology from the industrialised countries indicates that disposal of chemicals is an intricate and expensive undertaking which involves the use of designated dumping sites, specific incinerators and supportive clear policy decisions on all aspects of pesticide management.

PESTICIDES LEGISLATION

The government of Kenya, through the Ministry of Agriculture, established pesticide legislation under the aegis of the Pest Control Products Act of 1982 Cap 346. The implementation of that legal instrument commenced in 1983 through a board of management and a secretariat. The responsibilities of the board are "to regulate the importation, exportation, manufacture, distribution and use of products used for the control of pests and of organic function of plants and animals and for connected purposes." The organisation is therefore responsible for the entire management of pesticides in Kenya. Some of the constraints encountered during the implementation of the pesticides law are briefly discussed elsewhere (Kibata, 1985).

The board has however made remarkable achievements as regards registration of premises which handle pesticides and the actual products. So far 163 products out of a potential 450 have been processed through the registration system. Products to be considered for registration must be supported by favourable toxicological data as well as satisfactory biological performance, preferably generated locally. Suitable labels for those products must be submitted in both English and the local Swahili language before approval is granted by the board. Although the process may appear rather demanding on the part of the registrant, the broad objectives for the registration of pesticides is extremely novel and aims at improving the entire pesticide management system in Kenya. It is also consistent with the aspirations of the FAO/WHO "Code of Conduct" for better management of pesticides.

CONCLUSION

The use of pesticides will increase in scope and size as agricultural production is intensified to provide food and surplus produce for local and export markets. However, pesticides are a mixed blessing in that benefits accruing from their use may easily be dissipated through irresponsible usage. Information on the correct usage of the pesticides should be disseminated widely while the system of checks and balances on the agrochemical trade should be strengthened through established pesticide legislation. Research to identify more target oriented and safer delivery systems will certainly extend the life of the available pesticides. Pertinent issues such as disposal of expired pesticides as well as empty containers should receive attention at the earliest opportunity.

ACKNOWLEDGEMENT

The various sources of information cited in this paper i.e. Landell Mills UK, Needham Enterprises Nairobi and the Pest Control Products Board, Nairobi are gratefully acknowledged.

REFERENCES

Anonymous (1986 – 1990). *Annual Reports*. Pest Control Products Board, Nairobi, Kenya.

Anonymous (1989). *A Guide to the Marketing of Agricultural Pesticides in Kenya*. Needham Enterprises Ltd., Nairobi, Kenya.

Anonymous (1980–1989). The Agrochemical Market in Tropical Africa. Final Report. Landell Mills Associates, Bath, UK.

Kibata, G. N. (1985). Constraints in the implementation of Kenya's pesticide legislation. *Proc. USAID/REDSO/ESA Pesticide Management in East and Southern Africa Workshop*, Nairobi, March 1985.

Kiss, A. (1985). Pesticides: How to decide. *Ibid*.

Recommendations of the Conference

1. This conference affirms that the small farmer sector is one of the most important in the African economy and emphasises the urgent need for it to be recognised and supported by government and industry to the maximum extent possible.

2. This conference, pointing out that a small increase in food production in this sector would have a large effect on the food supply in Africa, urges ICIPE to use its resources and network of collaborating organisations throughout Africa to develop research projects to increase small farmer productivity, and protect their health by using environmentally safe pest management techniques.

3. Because of the success of this international conference, the meeting urged ICIPE and the Alumni Association to continue this as a regular series, holding meetings at appropriate venues at least every three years.

ICIPE/ALUMNI ASSOCIATION SYMPOSIUM ON COMMUNITY-BASED AND ENVIRONMENTALLY SAFE PEST MANAGEMENT

MAY 6–9, 1991

List of Participants

Mr. Ibrahim Mohamed Abu-Zinid
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Mr. Bekele Jembere Adjeh
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Mr. Adit Omer Ahmed
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. B. Amoako-Atta
ABN/UNESCO
P. O. Box 16496
ACCRA-AIRPORT, GHANA

Dr. F. A. Ayanwale
Department of Veterinary Preventive
Medicine and Public Health
University of Ibadan
IBADAN, Nigeria

Dr. Richard Kiome Bagine
National Museums of Kenya
P. O. Box 40658
NAIROBI, Kenya

Professor William B. Banage
Department of Biology
University of Zambia
P. O. Box 32379
LUSAKA, Zambia

Dr. Iyabo Bola Bassir
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Mrs. Dorcas Danta S. Bawo
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Ms. Byaruhanga Tarcilla Karungi
Makerere University
Forestry Department
P. O. Box 7062
KAMPALA, Uganda

Dr. M. F. B. Chaudhury
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. Z. T. Dabrowski
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. D. Dent
School of Pure and Applied Biology
University of Wales College of Cardiff
P. O. Box 915
CARDIFF CF 1 3TL
United Kingdom

Mr. Sylvain Coffi Dossa
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Mr. Edward O. Omolo
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. Suliman Essuman
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. A. El-Titi
Laudensanstalt fur Pflanzenshutz
Stuttgart
Germany

Mr. Charles Francis Mugoya
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Professor T. Gabriel
School of Pure and Applied Biology
University of Wales College of Cardiff
P. O. Box 915
CARDIFF CF 1 3TL
United Kingdom

Dr. Terekegn Gebreyesus
Chemistry Department
Addis Ababa University
P. O. Box 1176
ADDIS ABABA, Ethiopia

Dr. A. Hassanali
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Professor Peter T. Haskell
School of Pure and Applied Biology
University of Wales
CARDIFF, United Kingdom

Dr. Chaudhry Inayatullah
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. Alan Jackson
Technical Centre for Agricultural and
Rural Cooperation (CTA)
Convention ACP-CEE de Lome
Postbus 380
6700 AJ WAGENINGEN , Netherlands

Mr. Phiri Smoko James
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. (Mrs.) Phoebe Josiah
Division of Vector-Borne Diseases
P. O. Box 20750
NAIROBI, Kenya

Mr. Steven Joseph Wamala
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. Walter G. Z. O. Jura
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. (Mrs.) Alice Wangari Kamau
Crop Protection Department
Egerton College
P. O. NJORO, Kenya

Professor Abdelgadir Hassan Khattab
Faculty of Agriculture
University of Khartoum
SHAMBAT, Sudan

Professor Batan M. Khaemba
Department of Zoology
Moi University
P. O. Box 3900
ELDORET, Kenya

Dr. Baldip Khan
Kenya Medical Research Institute
P. O. Box 54840
NAIROBI, Kenya

Mr. Samuel Idrissa Kamara
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. Kuramochi Katsuhisa
Laboratory of Entomology
Obihiro University of Agriculture
and Veterinary Medicine
OBIHIRO HOJIADO, Japan

Mrs. Eucharia Unoma Kenya
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. G. P. Kaaya
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. Gilbert Kibata
National Agricultural Laboratories
KABETE, Kenya

Ms. Anne Wangui Kigo
Division of Vector-Borne Diseases
Ministry of Health
P. O. Box 20750
NAIROBI, Kenya

Ms. Susan Wangari Kimani
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Ms. Virginia Wamuyu Kimani
Pest Control Products Board
Waiyaki Way
P. O. Box 14733
NAIROBI, Kenya

Professor Fassil Gebre Kiros
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Mrs. Esther Ndaisi Kioko
Entomology Section
National Museums of Kenya
P. O. Box 40658
NAIROBI, Kenya

Mrs. Jedida Adhiambo Kongoro
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. J. Lancien
ORSTOM
P. O. Box 6
ENTEBBE, Uganda

Dr. Morris Wodamida Ogenga-Latigo
Makerere University
P. O. Box 7062
KAMPALA, Uganda

Dr. Wilber Lwande
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Mrs. Audrey R. Mabveni
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. Lawrence Chuka Madubunyi
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. Hassane Mahamat
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. Stephene Masingili Magesa
National Institute for Medical Research
Amani Medical Research Centre
P. O. Box 81
MUHEZA, Tanzania

Mr. M. A. Malik
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Mr. M. Gell Marangalla
Kenya Medical Research Institute
Vector Biology and Control Research Centre
P. O. Box 1578
KISUMU, Kenya

Miss Margaret Wanja Kinuthia
Coffee Research Foundation
P. O. Box 4
RUIRU, Kenya

Dr. G. Masina
University College of Swaziland
Luyengo Campus
P. O. LUYENGO, Swaziland

Mr. Jacob Cuthbert Mbapila
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Professor V. B. Mbaya
Biochemistry Department
University of Nairobi
P. O. Box 30197
NAIROBI, Kenya

Mr. Ahmed Salih Mohamed
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. D. Moore
CAB International Institute
Silwood Park
Buckhurst Road,
ASCOT, BERKS SL5 7TA
UK

Mr. Mugunga Muhinda
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Professor J. M. Mueke
Zoology Department
Kenyatta University
P. O. Box 43844
NAIROBI, Kenya

Mr. David M. Munyinyi
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. Mutuku J. Mutinga
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Mr. Githiri S. Mwangi
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. K. F. Nwanze
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
PATANCHERU, ANDHRA PRADESH 502324
India

Dr. Peter G. N. Njagi
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. N. Ngangu Massamba
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Miss Adele J. Ngi-Song
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. Firmin James Nguma
Tropical Pesticides Research Institute
P. O. Box 3024
ARUSHA, Tanzania

Dr. James Patrick Ochieng-Odero
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. George Willis Odhiambo
Pest Control Products Board
P. O. Box 14733
NAIROBI, Kenya

Professor Thomas R. Odhiambo
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. Maurice O. Odindo
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Mrs. Rhoda A. Odingo
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. Jondiko I. J. Ogoche
Chemistry Department
Kenyatta University
P. O. Box 43844
NAIROBI, Kenya

Professor Ochong' Okello
Department of Zoology
Kenyatta University
P. O. Box 43844
NAIROBI, Kenya

Dr. Y. A. Olaniran
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Ms. Elizabeth O. Oladimeji
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Professor Norah K. Olembo
Department of Biochemistry
University of Nairobi
P. O. Box 30197
NAIROBI, Kenya

Mr. Joshua F. Omange
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. John Henry Ouma
Division of Vector-Borne Diseases
Ministry of Health
P. O . Box 20750
NAIROBI, Kenya

Mr. E. Angus Onyido
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. J. B. Okeyo-Owuor
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. Hassan Farouk Partow
Environment Liaison Centre
International
P. O. Box 72461
NAIROBI, Kenya

Dr. Manoj Madhaw Rai
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Professor Dr. H. Rembold
Max-Planck Institut
Fur Biochemie
8033 Martinsried near Munich
Germany

Mr. Emil F. Rwekika
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. R. K. Saini
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Professor K. N. Saxena
ICIPE Research Centre
Mbita Point Field Station
P. O. Box 30
MBITA, Kenya

Dr. K. V. Seshu Reddy
ICIPE Research Centre
Mbita Point Field Station
P. O. Box 30
MBITA, Kenya

Mr. Fra Kujua Sika
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. Richard Otieno Sikuku
Pest Control Products Board
P. O. Box 14733
NAIROBI, Kenya

Dr. Timothy Kiprotich Arap Siongok
National Public Health
Laboratories Service
P. O. Box 20750
NAIROBI, Kenya

Dr. J. Ssennyonga
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Dr. R. W. Sutherst
CSIRO Division of Entomology
Cooperative Research Centre
for Tropical Pest Management
Gehrmann Laboratories
University of Queensland
Brisbane, Australia, 4072
AUSTRALIA

Dr. Evaliste Tama
Protozoology Section
Department du Laboratorie Veterinaire
B. P. 227
BUJUMBURA, Burundi

Dr. Getachew Tikubet
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Professor J. W. Truman
Department of Zoology
University of Washington
Seattle, Washington 98195
USA

Dr. L. Wadhmans
Rothamsted Experimental Station
Harpenden
Herts AL5, 2JQ
United Kingdom

Dr. Samuel Mukasa Waladde
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Mr. Bema Uronu
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

Mr. Richard Preye Uzakah
ICIPE Research Centre
P. O. Box 30772
NAIROBI, Kenya

THE ORGANISING COMMITTEE

Professor Peter T. Haskell	—	Chairman, Overseas Organising Committee
Dr. Mutuku J. Mutinga	—	Chairman, Resident Organising Committee
Dr. R. K. Saini	—	Alumni Scientific Secretary
Dr. Maurice Odindo	—	Member
Dr. R. K. Bagine	—	Member
Miss Rose A. Washika	—	Member
Mrs. R. P. Ortega	—	Member

SECRETARIAT

Dr. Mutuku J. Mutinga	—	Chairman, Local Organising Committee
Dr. R. K. Saini	—	Scientific Secretary
Miss R. A. Washika	—	Administrative Coordinator
Mrs. R. P. Ortega	—	Administrative Coordinator
Miss Susan Kagondu	—	Symposium Secretary

Typesetting: J. Wambui and D. Munene
Illustrations: N. Mwanga
Proof-reading: H. M. Adunga and D. Osogo
Design: W. Oyuko

ISBN 92 9064 062 6

All IPM specialists concerned with the development of sustainable pest and vector management technologies, as well as those involved in agricultural policy making and implementation will find this book most useful and timely. This book comprises 15 papers which were presented at the Symposium on Community-Based Environmentally Safe Pest Management held at the International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya. These papers deal with the components required for developing sustainable community-based pest management, the socio-economic aspects of the interface between pest managememt, technology and rural communities, as well as information, networking and development of human resources for pest management.

ICIPE
Science
Press