CHAPTER 1

Challenges in Pest Management in Agriculture: African and Global Perspectives

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Introduction

The major goals of agriculture worldwide are to produce sufficient food for the growing population, to generate incomes for farmers and to boost the Gross Domestic Product through the agricultural industry. With the increasing urbanisation there is a corresponding increased demand for food by the urban population, which is itself not directly involved in crop production.

Africa has a relatively large rural population, consisting mainly of small-holder farmers whose contribution to the economies of individual countries is highly significant. However one of the major constraints in crop production in Africa is the damage caused by diseases and pests, particularly arthropods, vertebrates, and weeds. In all world economies, wherever new innovations and high technological inputs have boosted agricultural production, pest problems have increased or have become more severe. World wide these pests account for losses of about 36% of the potential yield, and in storage, another 14% of the potential yield is lost (FAO 1973).

Africa has experienced many changes in agriculture in the last 5 decades, through improvement in farming systems, pest and disease management and increased yield of both staple and cash crops. Research aimed at producing crop varieties that are high yielding, and with other desirable characteristics like drought and pest tolerance has become intensified in the last 3 decades. However, these developments have not always reached the small-holder farmers or have been inadequate. Pests, particularly arthropods and vertebrates continue to ravage the crops and without proper crop protection systems, farmers shall lose all or a large proportion of their crops. These pests are controlled mainly with pesticides when these are available. However, serious problems often arise from their indiscriminate use, particularly through the disruption of the natural ecosystem and pollution. These consequences are unacceptable and call for the need to develop pest management strategies, which are appropriate, hence sustainable, and cost effective in maintaining the pest population below the economic thresholds, while at the same time conserving the environment.
The purpose of the chapter is to focus on pest management strategies and the challenges before us, particularly on feasible research and technologies that can be used to reduce the damage and losses caused by pests.

Table 1 provides a summary of general questions to be addressed in pest management interventions.

The global nature of pest problems

Pest problems are not unique to Africa. Devastating pest problems have been experienced in every continent and in some cases, pest species have caused problems across continents. The following five examples indicate the scale of pest problems on a global scale.

Table 1: General and specific pest management questions to focus attention on

General questions	Specific questions
WHERE DO WE FOCUS ATTENTION IN PEST MANAGEMENT	• What is the pest spectrum we are dealing with? • What is our current knowledge on specific pests? • In which areas of pest management are we most deficient in knowledge? • Where should efforts be focussed to manage certain pests?
WHAT ARE OUR BASIC NEEDS FOR SUCCESSFUL PEST MANAGEMENT	• Do we have the basic technologies to solve the most immediate pest problems? • What are the consequences of using these technologies? • Are the available technologies adequate to solve the pest problems?
CAN THE AVAILABLE TECHNOLOGIES BE INTEGRATED	• Is there the potential to integrate technologies for sustainability? • What are we missing in integrating the technologies? • Can we adapt technologies developed elsewhere to suit local conditions?
ARE RESOURCES AVAILABLE	• Are the pest management resources available and adequate? • Can we make better use of the available resources for greater impact?

Example 1: The Colorado potato beetle, *Leptinotarsa decemlineata,* in North America and Europe

Among the insect pests of potatoes, none are more destructive than the Colorado beetle, *Leptinotarsa decemlineata*. Until 1850s, *L. decemlineata* was a little known species indigenous to the Rocky Mountains (USA) where it fed mainly on *Solanum* spp. particularly *S. rostrum*. However, with the cultivation of potatoes, *Solanum tuberosum*, the beetle adapted to it very rapidly, and within 30 years, the insect had colonized most of North America's potato farms. The beetle is a voracious feeder, both in the adult and larval stages, causing complete defoliation of the potato plant. The population of *L. decemlineata* also evolved a number of host-adapted biotypes (Hsiao 1978). *Leptinotarsa decemlineata* permanently established in Europe in 1922 beginning with France then Germany by 1936, Netherlands by 1939, Poland in the mid 1950s, the western borders of the former USSR by 1959 and Turkey by 1976 (Hurst 1975). *Leptinotarsa decemlineata* became more devastating in Europe than in North America mainly due to its being an exotic pest hence not having natural enemies (Radcliffe 1982). Insecticide resistant population of *L. decemlineata* started appearing in North America and Europe hence compounding the problem of this pest.

Example 2: The Larger Grain Borer, *Prostephanus truncatus,* on stored maize in Africa

The larger grain borer, *P. truncatus*, was introduced into Africa in the early 1980’s from Central America through imported maize and has since spread to many countries in Africa (Makundi 1987). *Prostephanus truncatus* has now become one of the most serious pest of farm stored maize and dried cassava in sub-Saharan Africa. *Prostephanus truncatus* was first reported in Tanzania in 1981 (Dunstan and Magazini 1981, Golob and Hodges 1982). A new introduction, presumably an independent occurrence, was reported in Togo (West Africa) in 1984 (Krall 1984, Harnisch and Krall 1984). Outbreaks have also occurred in Guinea, Burundi, Kenya, Ghana, Burkina Faso, Uganda, Zaire and Malawi. In about 20 years, *P. truncatus* has become the biggest threat to stored maize throughout Africa. According to Golob (1997), value and weight losses approaching 60% can be expected following infestation with *P. truncatus*.

Example 3: The brown plant-hopper, *Nilaparvata lugens* (Stal), on rice in South East Asia

Rice, *Oryza sativa*, is by far the most important staple food crop in Asia. Approximately half of the people on earth obtain the most of their calorific intake from rice (Sogawa 1982). Among the pests of rice, the brown plant hopper (BPH), *Nilaparvata lugens* (Stal) is one of the most notorious pests. It causes damage to the rice crop directly by feeding, and indirectly by transmitting grassy stunt and ragged stunt viral diseases (Sogawa and Cheng 1979, Rivera *et al*. 1966, Lakshminarayana and Khush 1977). The BPH had long been a minor paddy pest in its endemic habitats in the tropics. However, since the early 1970s, the BPH has dramatically risen as a key pest, threatening rice production in tropical Asia (Sogawa 1982).

The BPH became the most important pest of rice in many Asian countries following the introduction of the modern heavy-tillering varieties, which require relatively large amounts of fertilizer (Saxena 1976). This high supplement of fertilizer appears to favour the increase of brown plant hopper populations due, to the luxuriant growth and a thick canopy. Although control was initially based on resistant varieties new biotypes of BPH appeared which were able to break the resistance. The new resistance breaking biotypes have become a great problem in rice growing areas of South East Asia (Sogawa 1982). The only way to manage BPH is possibly to introduce some new strains of resistant varieties to increase the diversity of the cropping system of rice (Saxena 1976, Sogawa 1982).

Example 4: Rhinoceros beetle, *Oryctes rhinoceros,* in the Pacific Islands
The rhinoceros beetle, *Oryctes rhinoceros,* is endemic to continental and insular South Eastern Asia from where it spread to the Pacific Islands. The preferred hosts of economic importance are coconut and oil palm, *Elais guineensis. Oryctes rhinoceros* occurs in dead standing plants, decaying wood, compost and saw dust piles, coconut stumps and other organic matter. Until 1966, the only promising method for controlling the rhinoceros beetle was biological control using the Scoleid wasp, *Scolia ruficornis*, but its impact was negligible (Caltagirone 1980). Other parasites or predators either have not become established in the new areas, or have not been effective. Pathogenic nematodes and fungi found in rhinoceros beetles have not proved effective control agents. Due to this failure to control the rhinoceros beetle, further studies on diseases of the beetle were carried out in Malaysia, Fiji and Western Samoa, which led to the discovery of a baculovirus, *Rhabdionvirus oryctes,* which is highly effective to the larvae of the rhinoceros beetle (Caltagirone 1980). From 1967, the virus was introduced in Western Samoa, Fiji Islands, Tonga, Wallis Island, and Samoa where it established well. This became the first successful biological control against the rhinoceros beetle using a pathogenic organism.

Example 5: The pesticide regimes in cotton
The problems of pesticide dependence are clearly shown by the cotton industry in Nicaragua, Egypt, the USA and other countries which grow cotton. In Nicaragua, the cotton industry took off in 1949. In 1960, cotton was a major export crop and by 1965, the export value of cotton was 50% of all exports in terms of value. However, during this period there was also a high dependence on pesticides to control pests. About 30 applications of pesticides were used per season. Although the yield increased, the cost for pest control also increased. Seven species of insects namely, *Heliothis zea*, *Spodoptera sunia*, *Bemisia tabaci*, *Anthonomus grandis*, *Trichoplusia ni, Sacadodes pyralis* and *Spodoptera exigua*, were the major pests of cotton in Nicaragua. Some of these pests were considered insignificant before pesticides were used widely, but achieved pest status as use of pesticides increased. Despite the repeated use of large quantities of pesticides, there was a drop in production. In addition, pesticides residues were found in beef, rendering it unacceptable for export.
In Tanzania there are several pests causing damage to cotton. However two insect pests, the American bollworm (*Helicoverpa armigera*) and cotton aphids (*Aphis gossypii*) are the most important. The twp pests cause yield losses of 30-50% annually (Kabisa *et al*. 1997). Application of oil based insecticide formulations is the most common control method against the two pests and a total of six applications is recommended (Ng'homa 1999). Despite this, and a range of other chemicals which could give effective control of the pests, there has been a downward trend in the yield of cotton in Tanzania due (Kabisa *et al*. 1997, Kapingu 1992). In addition, a calendar based treatment regime of cotton is expensive and hence not affordable by most small-holder farmers.

An overview of past developments in pest management
Agriculture, which developed as man changed from a fruit collector and hunter to crop producer, has always faced the threat posed by pests. The earliest attempts to control insect pests using pesticides involved the burning of "brinestone" (sulphur) as a fumigant (Ware 1975). As recently

as 1940, pesticides supply was limited to several arsenicals, petroleum oils, nicotine, pyrethrum, rotenone, sulphur, hydrogen cyanide gas and cryolite. During the World War II, the chemical era was opened with the introduction of a totally new concept of pest control chemicals, namely the synthetic organic chemicals.

The success of the organic synthetic pesticide industry has led to diverse chemicals being produced in very large amounts. The early-synthesized chemicals were of broad spectrum, had long persistence and were relatively cheap. However, many of the organochlorines, were replaced by organophosphates, carbamates and synthetic pyrethroids, which although more toxic and relatively more expensive, were less persistent. Despite the benefits realized by application of synthetic organic insecticides, various shortcomings were detected in the late 1950's and early 1960's. These included development of resistance, secondary pest outbreaks, pest resurgence and toxicity to man and other non-target organisms. These limitations led to withdrawal of some of the pesticides and the development of substitutes, which in some cases were more toxic. The publication of Rachel Carson's (1962) book, *The Silent Spring*, brought about awareness among scientists, politicians and the public on the adverse effects of pesticides on the environment. This marked the beginning of another era in our approach to pest management. Thus more attention was focussed on alternative approaches, including biological control, cultural methods and integrated pest management (IPM).

In the 1970s and 1980s, the focus was on use of less persistent and more target specific chemicals, which in some cases, were incorporated in IPM programmes. The management of pests in the 1990s focussed on a better understanding of the ecology of pests and development of novel approaches, which are ecologically sound. Thus from the era of pesticides, we have seen great developments in the areas of IPM, ecologically based control methods, developments in new formulations and application technology and more environmentally friendly materials for pest control.

Impediments to pest management

Ignorance

One of the major impediments to sustainable crop protection in Africa has been ignorance, particularly of the pest organisms and their associated parasites and predators. This problem is widespread in Africa, and poses new challenges in pest management. Furthermore, a large proportion of the population of Africa is rural based and illiterate. This renders dissemination of pest management technologies a difficult task, especially when coupled with the lack extension staff.

Many research establishments in Africa lack the necessary skills and equipment to perform necessary tasks to resolve the taxonomy of the pests which cause problems in agriculture. However, the major problem is not that the countries are too poor to fund such studies, but rather because governments do not always recognise the benefits which can accrue from this research. Plant protection research is given low priority in government funding, therefore it has accompanied by underdeveloped scientific infrastructure, and inadequate personnel. These trends have to be reversed in future if we are to increase the small farmers' output and achieve our goals of excellence in pest management and increased production.

Pest resistance, resurgence and secondary pest outbreaks

An increasing number of pest species have developed resistance to pesticides in the past few decades. Resistance develops as a result of powerful selection imposed on the pest population by the pesticide. The major concern on pesticide resistance is that once it occurs in a population, there are no ways to restore susceptibility (Busvine 1980). With the continued and excessive uses of pesticides in Africa, it is inevitable that pest resistance shall increase. This implies that since pesticides constitute the major tool for the control of pests in agriculture there shall be a continuous need for new chemicals that may not be readily available due to the extremely high costs of development, and pressure from environmental groups. The need for alternative strategies in Africa shall therefore be more urgent.

Chemical control has elevated certain pest species from relatively innocuous to highly destructive levels simply by eliminating their natural enemies, which keept their population levels under control. These "secondary" pests have become a serious problem in many crops. For example, the white wax scale, *Gascardia destructor* (Homoptera: Coccidae), occurs on citrus in southern Africa. The white wax scale is under natural control and is usually very rare. However, when persistent organophosphate insecticides were used to control the red scale, which is the primary pest, the natural enemies of the white wax scale were killed and it increased in numbers making it a secondary pest (Samways 1981).

Environmental contamination

The unprecedented environmental persistence of many of the synthetic organic insecticides, especially the organochlorines, together with the broad-spectrum activity of compounds manufactured since World War II, has led to substantial reduction in the use of many compounds in the developed world. However, in Africa, the need to combat food shortages and the demand for higher yields of cash crops, has attributed to the continued expansion of the pesticide market. There is an increasing concern about the toxic hazards to man, wildlife and domestic animals due to residues in the environment, which find their way into human food. Traces of these chemicals may lead to chronic toxicity (Busvine 1980).

Increasing pest problems – Exotic and endemic pests

Exotic pests constitute one of the most serious constraints to Africa's goal to attain self sufficiency in food crops and production of raw materials for industry. Exotic pests like the cassava green mite and the larger grain borer, were introduced undetected. The lack reinforcement of rules and regulations based on sound scientific knowledge particularly of the biology and ecology of the pests, suggests that exotic pests may not be easily prevented from entering and spreading across new territories. There is need therefore to evaluate the legislation and quarantine procedures for the management of exotic pests in Africa. However, the success of quarantine measures in future must aim at protecting bio-geographical areas and not individual countries. This should be based on realisation that the larger the landmass covered by uniform quarantine regulations, the greater the protection achieved. In addition, the compliance with legislation can only be achieved through continuous persuasion and community education.

The "pesticide treadmill"

The last fifty years have shown that availability of inexpensive pesticides led to less damage of food and cash crops. However, with the continued and widespread use of the same chemicals, resistance has increased in a wide range of pest species. Consequently there is a trend to use more pesticides in Africa and could stimulate a tendency to apply stronger doses more frequently with the hope to combat the resistant species. This pesticide spiral, or "pesticide treadmill" (van den Bosch 1978), is likely to lead to environmental backlashes such as pollution and secondary pest outbreaks. This implies that, in future, we need to develop alternative strategies especially those which focus on bio-control in order to reduce the chemical selection pressure on pest populations.

Future developments in pest management technologies

New pesticides and application techniques

New pesticides are needed to replace compounds currently considered unsuitable to combat resistant pest species, or compounds which are considered environmentally unsuitable due to toxicity to non target organisms. In many cases, high cost of pesticides such as synthetic pyrethroids may also be an important factor that limits the scope of use of some pesticides. However, in view of the costs involved in developing new compounds, there is reason to develop new application techniques aimed at reducing the quantities applied as well as to increase selectivity on target pests. Developing pest management strategies with minimal disruption of the environment is also necessary. With such foresight the problems experienced in the use of certain pesticides shall be avoided and the prospects for efficient, safe and economic pest management shall be realised.

Pheromones

Pheromones have various functions in insects. These include aggregation (e.g. swarming of locusts), dispersal (e.g. in the domestic cricket, *Acheta domesticus*), cohesion (e.g. bees), sex (e.g. in the armyworm, *Spodoptera exempta*) or growth regulation (e.g. in the locusts). How can pheromones be used in pest management? The best opportunities to make for their useful application are:

- Sex pheromones to attract the opposite sex in traps. Sex pheromones have been extensively used to monitor population size of armyworms, *S. exempta*, and are very useful for early warning systems that indicate the severity of forthcoming armyworm outbreaks. Other potential targets for pheromone use in pest management include control of the bollworm.
- Aggregation pheromones to bring individuals together for various purposes, including mating, feeding sites and to defend a colony. For practical pest management, the aggregation pheromone produced by the larger grain borer, *P. truncatus*, is currently being used to monitor the incidence of the pest in stores.
- Growth and development pheromones in the case of locusts changing phase from solitary to gregarious forms could potentially be disrupted to prevent swarming.

The major constraint in using pheromones is the likelihood of developing resistance, particularly when a single component of the pheromone is used. To prevent this happening, the release of the pheromone must be in the right concentration, time and distance. The synthesised pheromone must also be very close to the natural one to prevent the target insect from discriminating against it.

Materials of botanical origin (biopesticides)

There is a great variety of pesticidal plant alkaloids, but many of them are not being used extensively for pest control at present. The most successful materials of botanical origin for control of pests have been the pyrethrins. However, pyrethrins are not photostable and therefore, are not very useful for control of field crop pests. The search for newer materials, including Azadiractin (from the neem tree, *Azadirachta indica*) and Tephrosin (from *Tephrosia vogellii*) is being intensified and has a great potential for pest management in Africa. Thus, this field of research can be an important part of plant biodiversity studies. The potent botanicals with desirable properties can be screened for toxicity against the target pests, and analogues could be synthesised to overcome some of the limitations of the naturally occurring compounds.

Biological control

Biological control is the action of parasites, predators and pathogens in maintaining organisms density at a lower average than would occur in their absence (van den Bosch and Messenger 1973). Notable successes in biological control have been in those cases in which man has attempted deliberately to reduce populations of pests by manipulating their natural enemies.

Among the first attempts of biological control in Africa was the introduction of the Australian predatory beetle, *Lindorus lophanthae* (Coleoptera: Coccinnelidae) to control red scale (*Anidiella aurantii*) (Homoptera: Diaspididae) on citrus in South Africa (Samways 1981). Other biological control programmes have been on cassava where in 1971, a species of spider mite that attacks cassava was seen for the first time in Uganda. This pest, identified as the green cassava mite (*Mononychelus tanajoa* Bondar), is native to South America (Lyon 1973). This mite increased in numbers to devastating proportions due to a favourable climate and freedom from natural enemies. The mite has since spread throughout the cassava belt of Africa and has been a threat to a crop that is frequently grown in marginal soils and is a major food source during severe droughts.

Exotic phytoseiids have been selected as the primary biological control agents against *M. tanajoa* (Yaninek 1985). Releases of more than two million eggs and actives of seven species of the phytoseeiids were made as early as 1984 in Benin, Nigeria, Ghana, Congo, Gabon, the former Zaire, Burundi, Rwanda, Kenya, Zambia and Uganda (Yanninek *et al*. 1989).

In the 1970s, another cassava pest, the mealybug *Phenococcus manihoti* (Homoptera: Pseudococcidae), sprung into prominence in the Congo republic and the Democratic Republic of the Congo (formerly Zaire) (Bennett and Greathead 1978). The only natural enemy of this pest present in Democratic Republic of the Congo during the outbreak was the predatory larva of the butterfly *Spalgis lemolea* (Lepidoptera: Lycaenidae). However, significant achievements have been made in the control of the mealy bug by the predatory parasitoid *Epidinocarsis lopezi*.

For many other crops in Africa, pesticides cannot be used, as they are expensive or have serious residual effects. Therefore, the major challenge will be to seek for biocontrol solutions using indigenous natural enemies or other biocontrol agents including microbial organisms, genetic approaches, plant resistance, and even autocidal techniques. A success story using autocidal techniques was reported in Unguja Island (Zanzibar) Tanzania where the tsetse flies, *Glossina* *austeni* Newstead, were eradicated by releasing sterile males into the population (Kiwia *et al*. 1997).

Africa will continue to face problems caused by both exotic and endemic pest outbreaks.
Bio-control of these pests will be the basis for sustainable, economically sound and environmentally safe pest management strategy. However, successful bio-control programmes will require comprehensive studies, which must address the whole ecosystem. Although such studies were very limited in the past, there has been a vast increase in recent years, covering such pests as stem borers, cassava green mite, the larger grain borer, cassava mealy bug, etc. These studies need to be pursued more intensively in the future, if we are to prevent devastating crop losses.

Future of chemical control of pests

Chemical control of pests for the future shall have to focus more on the efficient use of bioactive substances, and become more targeted on the pest species in order to reduce the disruptive effects on the environment and other non-pest and beneficial organisms, including natural enemies. Traditionally, the application technology has consisted mainly of sprays, granules and dusts, baits and fumigants. These formulations have one major shortcoming, namely the pest does not necessarily take up all the applied material. Therefore, in future, application of new chemicals needs also to focus more on the delivery pathways to target pests. The most desirable approach will be to develop a controlled delivery system or formulation against the target pests, which will ensure protection of the active ingredients and release of the active ingredients only when needed. Formulations using polymetric matrix (e.g. lignin, saw dust, bark and waste paper) are now available for a limited number of pests in Europe and America, using micro-encapsulation techniques (Wilkins 1978). The advantage of using the controlled release technique is that effective control of a pest is achieved because the chemical release by the matrix matches the infestation pattern for sufficient time to ensure that the crop is protected (McFarlane and Pedley 1978).

Despite the search for new compounds, it is evident that no single type of pest control agent shall be expected to solve all problems pertaining to production of food and maintenance of high public health standards. We clearly need an arsenal of pest control weaponry of multiple types and potentials. Therefore, pesticidal compounds of the future shall have to be characterised by their diversity in terms of formulation, methods of application, target specificity, non-persistence and low toxicity in the environment.

Use of pathogenic microbial and hormone mimics

Pathogenic microbials

Viruses, bacteria, protozoa, fungi, rickettsia and nematodes perform important roles in the dynamics and natural regulation of insect populations in nature. Microbial pathogens may cause outright death or may interfere with insect development, reproduction, insect resistance to attack by predators or parasites. Microbials may also influence the susceptibility of insects to control by means of insecticides (Falcon 1971).
The use of microbials such as *Bacillus thurungiensis* has reached commercial success in the control of Lepidoptera larvae. Many other microbials have been found to be associated with

several species of insects, but these have not been exploited commercially in insect pest management (Weiser 1970). Most field studies have been conducted with viruses and bacteria. However, fungi, rickettsia, protozoa and nematodes have not been used as extensively because of their extreme dependence on environmental conditions (Tanada 1959). This does not however, rule out their potential use for future management of insect pests in Africa. Fungi are limited in the field because of their great dependence on stringent humidity conditions although the genus *Beauveria* appears to be the most promising for some pests because of its high toxicity (Ferron 1978).

Protozoa offer considerable promise in microbial control in view of the large number of species found on insects. Their potential is however, limited by the relative difficulties of identifying and producing them in large quantities (Weiser 1970). Nematodes could eventually become significantly effective agents because large numbers of them are internal parasites of insects (Finney 1981). Certain microbials used elsewhere for pest management have great potential for future control of some important agricultural pests in Africa. These include *Beauveria bassiana* against banana weevil (*Cosmopolites sordidus*), *Venticillium lecannii* against the sweet potato white fly (*Bemisia tabaci*), *Metarhizium anisopliae* against *C. sordidus*, and several other pests. The effectiveness of most of these microbials depends to a large extent on factors that govern their dispersal capacity and pathogenicity. Dispersal may be through infested hosts, on bodies of animals , climatic and physical factors or their own activity. Therefore, in future, it is of utmost importance to understand the dynamics of infections of the pests by their parasites. Studies should focus on identity, pathogenicity, host resistance and dispersal mechanisms and whether control by microbial pathogens can be used alone or in combination with other control measures for effective management of the target insect pests. Studies should also focus on the specificity of the pathogen. For example, polyhedrosis viruses are only infectious on only one group of insects. This is however not the case with non-inclusion viruses (Weiser 1970).

One major constraint is the lack of persistence. When the pathogens are highly efficient they will normally kill the whole population of hosts, which will necessitate re-application in new outbreaks of the pest. Therefore, a good pathogen should have both good persistence and spread and should be self-perpetuating in order to control a re-occurring pest problem (Burgess 1980).

Hormone mimics

Insects produce different types of hormones that control certain behavioural and physiological processes. Among the hormones which have been the target for use in insect pest management is the juvenile hormone that controls the process of maturation to the adult form. Analogues of the juvenile hormone have been used against certain pests whereby the insect dies because of morphological abnormalities. The major disadvantage of using juvenile hormones is that the death is slow and therefore, the larvae continue to cause damage for some time before they die. Some compounds originating from plants cause precocious metamorphosis in insects. The search for such compounds, commonly referred to as precocenes, could increase the available range of bioactive materials against pests.

Novel approaches in pest management

Use of recombinant DNA technology

Recent developments in genetic engineering of crops have produced genetically engineered seed and horticultural products. This new development suggests that it is now potentially possible to use this technology to produce virtually every type of crop with a few or several desirable properties. The greatest uncertainty about genetically engineered crops, however, is that they could become pests themselves and lead to problems similar to those we are trying to resolve, especially if they are out of control of the normal farming system. This is especially likely to happen if the genetically engineered crop is resistant to drought and diseases or it survives under stressful conditions such as low fertility. Such adverse consequences have to be properly addressed before we make use with confidence of genetically engineered crops to increase yields.

Genetic engineering could be used to build-in protective mechanisms against pests in crop plants or animals. For example, genes of chrysanthemum (which produce pyrethrins) could be introduced into crop plants such as maize or sorghum, then these crops would produce the pyrethrins for protection against various insect pests. Another approach could be producing a certain agent through genetic engineering in microbial organisms, harvest the agent and use it against certain pests. The major draw back of genetically engineered crop, however, is their acceptance by the general public. This needs to be addressed through public education.

Cloning to produce resistant crop plants

Primarily, pest-resistant crops are produced by breeding. Therefore, it is likely that through mutations cells could be cloned so that a plant with resistant capability, but which retains all the other properties of original plant is produced.

Activation of chemical defence

This approach in pest/disease management is analogous to immunisation in animals. The technique activates the defence systems in plants by treating them with a variety of antigens which are either virulent or avirulent. The idea is that the infectious agents will elicit the accumulation of metabolites similar to antibiotics around the site of infection and rapidly attain concentrations that inhibit the development of the infectious agent.

Breeding for chemical host resistance

In this approach, disease control could be achieved if the plant or animal would possess an inherited capability to biosynthesise larger amounts of the resistance compounds more quickly following infection than under normal circumstances. An example could be cotton plants which produce chemicals that resist infections by fungi or bacteria. Similar to strategies for integrated pest management against insects, the development of plants for maximum disease resistance rather than for maximum production may be more desirable because the costs for plant protection by pesticides would be lower.

Legislation in pest management

Legislation aims at keeping pests from entering a non-infested area. In many cases however, the legislative measures merely succeed in delaying the entry of pests, but ultimately, they may gain entry. African countries are going through a period of economic liberalisation, which implies removal of restrictions that may result to free transfer of plant and animal materials across borders. The dangers of introduction of new pests to non-infested areas are therefore likely to increase. This calls for more stringent cross border checks and where legislation has failed to keep pests out, quarantine measures have to be introduced.

An effectively implemented pesticide legislation is essential, particularly to prevent haphazard uses of pesticides. This will reduce chances of environmental degradation, development of resistant populations of the pests, and of other associated problems.

Plant resistance

Plant resistance is generally defined as the ability of a plant to avoid, tolerate or recover from attacks of pests under conditions that would normally cause injury to other plants of the same species (Beck 1965). There have been significant developments in breeding for plant resistance to some important insect pests (e.g. against bean maggots or stem borers). Plant resistance to pests will definitely play an increasingly important role in future pest management in Africa. For example, some sorghum cultivars are known to be resistant to both field and stored products pests (Makundi 1996; Makundi and Wilkins 1995).

Ecological approaches and Integrated Pest Management (IPM)

It is certain that only with adequate ecological information can most intelligent use of pesticides be made. Adequate information is lacking in the control of many pests in Africa. Therefore, the way forward is to create and make available information, especially on pest ecology, in order to implement a sound management with little or no reliance on chemicals. An understanding of insect biology and bionomics is essemtial for management of most pests (Banwo et al. 2001). The formulation of an effective management package for any particular pest complex will require the integration of biological, chemical and cultural practices. However, this requires a thorough analysis of the agro-ecosystem in its proper ecological, sociological and environmental setting. Among factors that need to be understood include: density dependent factors, behaviour patterns and spatial distribution. One essential consideration in the ecological approach is the capability to forecast pest outbreaks (Makundi et al. 1999) This is of paramount importance because it will allow us to know:

- when to anticipate the beginning of an outbreak and its subsequent development pattern
- the damage potential of an outbreak
- the appropriate timing of control operations

Knowledge of the population dynamics and ecology of the pest has a particularly important function in the development of models to predict outbreaks. For example studies in rodents has enabled formulation of ecologically based management systems for multimammate rats in Eastern Africa that are aimed at reducing crop losses and disease prevention (Stenseth et al. 2003; Makundi and Massawe 2003; Makundi et al., 2005; Makundi et al. 2006; Massawe et al. 2005; Odhiambo et al. 2005; Davis et al. 2006). Unfortunately, we understand relatively little of the ecology and population dynamics of many crop pests (Makundi 1999). What is especially lacking is information on pest history, including the factors which in the past have led to outbreaks. For example, weather changes can contribute a lot in the control of pests because of its influence on the pest population size, rate of growth or migration patterns. A good example of the influence of weather patterns can be found in relation to arthropod pests and rodents. Ver few studies have been conducted in Africa to show the influence of climatic conditions on vertebtare pests. However, in recent years such studies have been reported in East Africa that show the influnce of rainfall on rodent species (Makundi 1995; Makundi et al. 1999, Makundi et al. 2003; Massawe et al. 2003, Leirs et al 1987). In future therefore, we need a better understanding of the mechanisms influencing the occurrence of outbreaks and on the basis of this knowledge, build models that can be used for their prediction.

Integrated pest management (IPM) is a new direction in crop protection. IPM aims at conserving and enhancing naturally occurring limiting factors, such as parasites and predators, as much as possible, in order to contain pest organisms below economic damage thresholds. Because of the problems that accompany purely chemical control of pests, it is desirable, wherever possible, to substitute in an integrated manner, cultural and biological practices for chemical control, and to use chemicals, if necessary more judiciously (Getz and Gutierrez 1982). In this approach, chemical control shall be used selectively, and only when the other techniques have failed to keep the population of pests below acceptable levels. IPM functions in the context of the associated environment and the population dynamics of the pest species, and therefore, a good understanding of the economic damage thresholds and overall importance of the natural mortality factors is essential (Brader 1979). A major constraint in developing IPM systems in Africa is the inadequacy of in the agricultural extension services, research and training. IPM programmes carried out successfully elsewhere cannot be simply transferred to the local situation. This implies that research on IPM should be carried out at a local level. It also calls for strengthening of cooperation and communication between scientists, extension workers and farmers than has been the case in the past. In addition, further training on IPM strategies will be essential at all levels.

IPM strategies were first developed and practised in North America and Europe, but soon found acceptance in the rest of the world. Many countries in Africa have introduced IPM programmes to combat pest problems and IPM is accepted as the ultimate solution. Examples of successful programmes include management of *Spodoptera littoralis* and *Heliothis armigera* in cotton, *Sesamia cretica*, *Chilo agamenon*, *Ostinia nubilalis*, *Spodoptera littoralis* (Mgoo et al. 2006) and *Rhopalosiphum maidis*) in maize, *Chilo agamenon* and maggots of the tabamid *Atylotus agrestis* in rice. The success of these programmes is encouraging because these crops are widely grown in Africa. They have similar pest problems and therefore the IPM approach for these crops has the potential for easy adaptation in many countries.

Information Technology: Will it affect the way we manage pests?

In a world that is becoming closer and smaller everyday due to new developments and spread of information and communication technology (ICT), Africa is still lagging behind in terms of infrastructure, access and expertise in ICT. Enhancing the speed by which we are able to access pest management information and apply or adapt it to solve local problems will enable Africa to develop truly sustainable crop management strategies.

Data bases and literature bases are available, but these may not be easily accessible to our pest management managers for direct application or adoption in the diverse pest situations where they are operating. National efforts to increase accessibility of these data and information bases are of utmost importance in future pest management operations in Africa

Summary

The major challenges in pest management in agriculture in Africa shall include:

- Reducing the dependence on pesticides, thus avoiding the limitations observed in the past 50 years.
- Overcoming peoples ignorance on the pest species and their associated community of parasites and predators, which have dire consequences on the whole ecosystem.
- Keeping out exotic pests, which can have a devastating blow on production of some crops
- Developing and strengthening indigenous technologies for pest management (IPM, biocontrol) and making available to farmers materials for pest management which are affordable, safe, effective and environmentally friendly (e.g. microbials, botanicals, pheromones, genetically engineered products, etc.)

Both legislative and quarantine measures will have a significant role to play in pest management in the future, but only when practised on a wider geographical area.

Information and communication technology will affect the way we acquire and make use of pest management strategies. Africa is therefore faced with the challenge of building up and improving its infrastructure and expertise on ICT to strengthen pest management on the continent.
Research facilities and training of scientists, extension and farmers must be well supported to meet the challenges ahead, if the dangers posed by pests in agriculture are to be minimised in a continent trying to feed an increasing population.

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