Cotton Disease Control: Contrasting approaches

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ABSTRACT

Cotton was one of the first crops for which IPM systems were designed, primarily as a response to the appearance of pesticide resistance in important cotton insect pests. The principles of IPM are now widely disseminated, but where IPM systems have been successfully implemented, they have been targeted at one or two primary pests. More often than not, these pests have become a major problem as a consequence of the over dependency on pesticides. It is rare for the practice of IPM to be extended to integrated crop protection (ICM) whereby, management of insect pests is integrated with that of diseases, nematodes and weeds. The application of the principles of IPM to plant disease control is proving to be a slow and difficult process because disease control has never been as reliant on chemical control, as insect control used to be and because the cryptic nature of the causal organisms makes diagnosis and quantification much more difficult. Management options for cotton diseases are dictated largely by the socio-economic status of the target group, as illustrated with case studies from USA, Zimbabwe and Tanzania. Using the term IPM for disease management may not be appropriate, especially for small holders in Africa and may even hamper progress towards integrated crop protection.

Introduction

Integrated pest management (IPM) has become one of the most widely discussed concepts in agriculture and while there are examples of its successful application in cotton, successfully implemented IPM systems are generally targeted at one or perhaps two major pests. Often these are insect pests which have become a problem as a consequence of over reliance on a limited range of pesticides. IPM is also now used as a term which encompasses what should perhaps be known as integrated crop protection (ICP) i.e. integrated management of pests, diseases and weeds. But there are few examples of fully integrated multidisciplinary crop protection research, and even fewer, if any, of ICP systems in practice. The extension of IPM from its traditional usage of integrated management of insect pests to include diseases and weeds is proving to be a slow and difficult process.

Successful IPM systems have been applied under certain, clearly defined conditions:

- In large-scale commercial agriculture such as in the USA, or in centralised, state controlled production systems, such as occurred until recently in Egypt Alternatively, where the crop occupies a large area of contiguous small holdings with co-operation between adjacent growers in the implementation of control programmes, as is the case with cotton in the Sudan Gezira.
- Where there are one, or at most two, pests which have become a major problem due to pesticide use, as is the case with sucking pests in several African countries.
- Where over reliance on a small number of pesticides has led the development of insecticide resistance in the target pest, as has happened with *Helicoverpa* bollworm in India, Australia an elsewhere.

At least one and sometimes, all three of these conditions are fulfilled in situations where IPM programmes have been successfully adopted. In each of the examples given above, the IPM system has been designed for insect pest control. Where pest control models have been developed for computerised pest management decision making, disease and weed control is rarely integrated into the system. The exception to this may be the USA, where farmers are technically educated and the high cost of inputs makes computer systems cost effective.

Cotton disease management

Chemical control

Even in highly technified agriculture, few cotton diseases are controlled chemically. The use of foliar sprays of biocides active against fungi or bacteria, have been advocated for the control of *Alternaria* leaf spot [*Alternaria macrospora* Zimm.] of Pima cottons in Israel (Bashi *et al.*, 1983), occasionally against *Ramularia* leaf spot [*Ramularia areola* Atk.] (Cauquil and Sement, 1973). and against bacterial blight [*Xanthomonas campestris* pv. *malvacearum* (E. F. Smith) Dye] in India (Chauhan *et al.*, 1983).

Fungicides are, however, widely used in the management of soil and seed-borne diseases such as *Anthracnose* and *Pythium* or *Rhizoctonia* damping off (e.g. Wheeler and Ganaway, 1997) Pest control chemicals applied to the seed is highly targeted and cost effective and application methods can be very simple. This type of technology is therefore accessible to relatively small-scale producers. In several African

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countries where cotton is produced by large numbers of farmers with very small holdings, who are unable to afford inputs, seed dressings are applied at the ginnery before planting seed is distributed. In large-scale production systems, the chemical is applied by the farmer, to the seed and surrounding soil during mechanical planting as the seed leaves the hopper.

In developing countries such as Tanzania and Uganda, where the cotton industry has recently been deregulated and ginneries privatised, the private sector is reluctant to continue seed treatment, as the seed can rarely be sold at a price that realises sufficient profit, compared to crushing the seed for the production of vegetable oil. The main target for seed dressing chemicals is bacterial blight which is not perceived as an important problem. It can be difficult to explain to ginnery managers, that seed treatment is a component of an integrated management system which relies on host plant resistance, rotation and seed treatment, to be fully effective.

Chemicals are also used in the US for nematode control, particularly where the *Fusarium* wilt/root-knot nematode complex is a problem. Nematicide application is an expensive option and only viable where inputs levels and management standards are high enough to produce high yields.

Resistant cultivars

Deployment of host plant resistance remains the primary means of disease management for most cotton diseases. Resistance is the mainstay of management systems for the main cotton diseases of world-wide distribution: bacterial blight, *Fusarium* wilt and *Verticillium wilt*. The cost of developing cultivars with multiple disease resistance in developed countries is shared between publicly funded research institutes and seed producing companies. Costs to the seed producer then have to be recovered from the sale price of the seed. In developing countries, the costs have been met in the past, by publicly funded research institutes. Cotton seed in many African countries, has been issued free to farmers. Recent economic restructuring policies have encouraged a move away from research that is funded directly from central government, towards some system of funding through a levy on the producer and/or on the companies marketing the lint. In addition, the trend now is to sell seed to the farmer, rather than issue it to growers free of charge. This is advocated. as much as anything, to provide an incentive for ginning companies to continue providing dusted seed to farmers.

Cultural practice

Sound agronomic practice is fundamental to disease management in cotton. Several of the foliar diseases are caused by pathogens which over-winter in crop residues and survive poorly, or not at all, in the soil, once residues have decomposed. Typical of this type of disease are bacterial blight, *Alternaria* leaf spot and some of the boll rot diseases. Destruction or incorporation of crop residues at the end of the season and rotation, are effective tools in the management of these diseases.

Planting patterns which encourage airflow within the crop canopy and careful management of nitrogen fertilizer to avoid excessive vegetative growth, can be effective components of management systems for boll rot diseases.

Fertilizer management is important with respect to *Alternaria* leaf spot, particularly in the Upland cottons, which are predisposed to infection by the fungus by potash deficiency.

Integrated disease control

What difficulties apply in trying to design IPM systems for plant disease management? The first is a conceptual one of adhering to the use of the term IPM, in order to obtain donor funding for research. The term integrated disease management, (IDM) would be preferable if the system is targeted at an important disease (or diseases) and ICP if disease control is integrated with control of arthropod pests and weeds.

Historically, the pesticide industry was very successful in developing chemicals which were effective against their target insect. chemical control of plant diseases has been less successful and disease management has often relied on some form of integrated system. This has happened because diseases are more difficult to control with chemicals, as almost 100% coverage of the plant surfaces is required to prevent infection by air-borne pathogens. Furthermore, the causal organisms are more cryptic, often systemic within the host and sedentary in their feeding habit. Economic loss can occur before disease symptoms become visible. Host plant resistance has therefore been the mainstay of disease management, supplemented with chemicals and cultivation and crop sanitation measures. Although these management systems have been integrated in practice, the term IPM (or IDM) is rarely seen in the literature of disease control.

Integrated crop management

Before fully integrated crop protection programmes have been implemented, the current thinking in developed economies has moved on towards integrated crop management (ICM). ICM is a system in which pest management is one component of crop production which seeks to promote plant health as a whole, using husbandry methods which cause minimal erosion of the resource base and decreases the risk of environmental contamination.

Organic farming employs an ICM approach which goes even further in advocating practices which sustain soil health, decrease environmental effects and protect the health of the consumer. The concept of soil health is however, central to any organic system and to many

ICM systems. The preservation of soil health requires management methods which improve soil structure and fertility and encourage a balanced soil microflora. It is generally accepted that pests and diseases are rarely a major problem in fully organic farming systems. Soil health is promoted primarily by maintaining or increasing the humic content of the soil. This encourages beneficial micro-organisms and decreases the activity of soilborne plant pathogens. Plants which obtain their nitrogen in the form of ammonia as a result of microbial decomposition of organic residues, are less attractive as host for pests and diseases than plants receiving inorganic nitrate fertilizer.

Defining the target group for IPM programmes

The component technologies that can be successfully adopted depend largely on the economic status of the target farmers. The type of approach, or whether an IPM approach is appropriate, will depend to which of the following categories the target farmers belongs.

- Large scale/ high input, highly technified
- Small scale/high input technified
- Small scale/low input semi-technified
- Small scale/low input/non-technified.

Only the first of these groups are likely to fulfil more than two of the conditions for successful IPM implementation, set out in the introduction. The second group may fulfil them if farms are sufficiently close together and a single crop predominates. Both the first two groups will be prone to the development of pest and disease problems which are themselves, induced or exacerbated by prolonged pesticide use (iatrogenic). The third group are unlikely to have iatrogenic pest problems as they use pesticides too infrequently. However, they may still suffer from periodic damage by a primary pest such as one of the bollworms, especially in areas without a long close season and where crops with shared pests overlap one another. This occurs commonly in systems with cotton, maize and pigeonpea with respect to Helicoverpa armigera. The fourth group do not use pesticides and rarely experience pest and disease attack as a major constraint to production.

The adoption of an IPM package is much more likely if the starting position is one of pesticide over-dependency and an alternative system can be offered that substantially decreases pesticide use without a significant effect on gross margins.

Alternatively, the IPM approach may be recommended as a preventative measure, to prevent the development of pesticide resistance in the future. Zimbabwe is a good example of this, where the use of pyrethroids was restricted from their first introduction and farmers are also encouraged to use acaricides from a single chemical group for no more than two seasons.

In many African countries, few cotton farmers can afford to use pesticides. Nevertheless, an IPM approach may still be worthwhile but the rationale is different. In this case, the aim is to design a pest management system which does not incur additional costs but which gives the farmer a reasonable return on any additional labour required for its implementation. Commercial pesticides use must be kept to a minimum or avoided altogether.

Case studies

1. USA

It is only in the large scale production systems of the developed economies where IPM packages have been adopted which include disease and weed management.

A typical cotton farmer in the USA might use pesticides to control nematodes, weeds, seedling diseases and a range of insect pests affecting the crop at each growth stage (See Table 1). If such an intensive use of crop protection chemicals is to be cost effective, with minimal non-target effects, the farmer must be able to access information on damage thresholds and regularly monitor pest and disease levels.

2. Zimbabwe

An IPM approach was implemented in Zimbabwe but targeted mainly at management of bollworm pests in which the use of synthetic pyrethroids was restricted at the beginning of the season and permitted for a period covering no more than two generations of *Helicoverpa*. This approach has proved successful in controlling bollworms and preventing the development of pesticide resistance.

As yields increased, insufficient account was taken of the additional nutrients taken from the soil and fertilizer levels were below the minimum to maintain levels of available potassium on certain clay soils. As a consequence, late season potassium deficiency began to appear in cotton crops grown on those soils, characterised by bronzing of the upper canopy leaves. Potassium deficiency predisposes the foliage to infection by *Alternaria macrospora* (Hillocks and Chinodya, 1989) normally a weak pathogen on non-deficient plants. The arrival of moist weather conditions then stimulates sporulation of the fungus, the disease spreads and rapid defoliation occurs. *Alternaria* leaf spot has become a more common problem in several other cotton growing countries but this is due largely to increased cultivation of cotton cultivars derived from *G. barbadense* which are more susceptible to the disease. The management of this problem is difficult, large applications of potash fertilizer can help to some extent but the residual effects are minimal as the potassium is rapidly removed from the soil by luxury consumption by the crop and by leaching. It seems to be difficult to restore levels of available potassium on some clay soils once it falls below a certain level. It is far preferable to ensure that fertilizer application is sufficient to replace macronutrients removed by the crop. A period of fallow or cultivation of a root crop might raise the level of available potassium.

Integrated disease management in Zimbabwe involves the use of seed dressings to prevent damping-off, mainly by *Rhizoctonia*, rotation helps to control bacterial blight, mineral fertilization for *Alternaria* management, the use of resistant varieties for bacterial blight and *Verticillium wilt* and finally, uprooting and residue destruction also helps in blight control. Seed treatment with fungicides is a cost effective means of disease control and a range of application technologies are available to cater for large and small scale farming systems. The chemical can be delivered to the planting hole with the seed during mechanical planting or, for smallholders, the seed can simply be shaken in a tin with the fungicide dust.

3. Tanzania

The production system in Tanzania is characterised by a large number of farmers individually producing cotton on a very small scale. Under these circumstances pest and disease management have traditionally been centrally controlled and regulated. Inputs have been subsidised. Since the withdrawal of subsidies on farm inputs, most farmers do not use fertilizer or insecticide.

The most important disease is *Fusarium* wilt which is widely distributed on sandy soils and usually accompanied by root-knot nematode. Seed for planting is derived from the normal farmers crop and, previously it was distributed free of charge, through the Cotton Marketing Board. The disease was managed in the past, by a combination of resistant varieties and measures to ensure that planting seed did not carry the pathogen. Planting seed was derived from villages listed as free of *Fusarium* wilt on the basis of surveys conducted by the extension services. With the privatisation of the marketing of seed cotton and lint, it has proved difficult to establish the source of seed cotton and to prevent crop derived from villages with *Fusarium* wilt from being used as a source of planting seed. In addition, seed of wilt-resistant and wilt-susceptible varieties has become mixed to an unknown extent. The management options here are firstly, to continue with the development of resistant varieties and secondly, to design a seed multiplication system that precludes the possibility of seed becoming infected. The implementation of such a scheme is prevented by limitations on the resources available for seed multiplication. Seed production could be conducted in areas where the soils suppress *Fusarium* wilt. This must be the long-term objective if the disease is not to spread further.

For those farmers whose land is already infested with *Fusarium* wilt, resistant varieties offer good control, except where root-knot nematode is also present in the soil. Under these circumstances there may be some potential for managing populations of the wilt fungus and root-knot nematode by rotations with cassava. In the longer term, improved resistance to root-knot may be required for the local cultivars.

Requirements for IPM implementation and can they be fulfilled for integrated disease control?

Some lessons can be drawn from experience with IPM for insect control, in the development of integrated disease management:

Information available or can be obtained on economic thresholds and damage caused by the target pest of pests, is known to exceed the economic threshold.

A scouting system can be adopted on which to base spray schedules (or other control methods)

The correct application equipment is available and implementers are trained in their use and in safe pesticide use and the calibration and maintenance of delivery systems.

There is ready and reliable source of high quality pesticides that are IPM-compatible.

If these criteria are applied to IPM for insect pest management alone, then it is clear that for smallholder production systems in many developing countries, some or all of these conditions cannot be fulfilled. If the IPM system is required for the non-technified sector, without the use of synthetic pesticides, the first two conditions must still apply. In other words, alterations to the present farming system will not be adopted unless, not only is the target pest causing economic damage, but also, it must be perceived as doing so by the farmer. If he is to quantify the likely damage, the farmer must be able to measure the pest population over time.

Currently, there is insufficient information on the economic threshold level for pathogen and nematode populations or for the damage to the crop. This is true for developed economies and must therefore be more of a problem in developing countries. Collection of this type of information is more difficult for diseases than for insect pests. Furthermore, the cryptic nature of the causal organism and the often confusing nature of disease symptoms, as opposed to those caused by insect pests and abiotic stress, make it difficult for unsophisticated smallholders diagnose and assess economic damage.

What the future holds

Genetic manipulation will continue to be the mainstay of cotton disease control, using conventional breeding methods to combine genes from strains within the species and between species. Genetic engineering may be increasingly used to transfer genes from other species, where there is insufficient variability for disease resistance. Host plant resistance will be used for control of bacterial blight, *Fusarium* and *Verticillium wilt*. In the case of the seedling diseases, where there is little genetic resistance to exploit, control will be based on the use of conventional seed dressing fungicides, but the trend towards more sustainable soil management methods, will improve natural biological control in the soil. The effectiveness of biocontrol agents for soil-borne pathogens will be improved by genetic engineering and it will be more common to plant seed pelleted with biocontrol agents and perhaps also, mycorrhizal preparations.

Crop protection activities will be increasingly integrated at all levels. This can be seen already at the genetic level in the Multiadversity Programme (MAR), whereby a number of morphological traits are combined to produce plants with improved resistance to pests, disease and drought. Some of the MAR cultivars carry resistance to seed deterioration and seedling disease (Bird, 1982; see also El Zik in proceedings of this Congress). The extent of resistance to insect pests conferred by these traits is in most cases, insufficient to alone decrease pest damage below threshold levels. The use of these cultivars for insect pest management has to be integrated with other measures. For instance, in tests conducted in Arizona, the use of cultivars with the nectariless trait, allowed a delay of two weeks before the first spray for pink bollworm had to be carried out.

Expert systems will be developed for integrated crop management, incorporating integrated crop protection.

The picture is rather different for the smallholder in a developing country, whose access to these technologies is limited by his economic status. With the trend towards charging the cotton farmer for his seed that is taking place in Uganda and Tanzania for instance, the benefits of biotechnology are unlikely to be affordable without a move towards economies of scale in cotton production. In the shorter-term, pest management systems are required which are compatible with the level of resources available.

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Table 1. Case study 1: Pest management in advanced agriculture.

TIMING	TARGET PEST	INTERVENTION
Pre-plant	Root-knot and reniform nematodes	Nematicide application
	Grass weeds	Herbicide
Pre-emergence	Seed rot and pre-emergence damping-off	High quality acid delinted seed
	Post-emergence damping-off/Thrips	Seed dressing(Fungicide/insecticide)
		In-furrow treatment
	Broad leaf weeds	Herbicide
Vegetative growth stage	Early season pests	Soil-applied insecticides
	Aphids	Selective insecticides
	Vascular wilts/nematodes	Resistant varieties
	Bacterial blight	Resistant varieties
	Leaf eating pests	Non—pyrethroid insecticides
		Bt
Fruiting growth stage	Boll worms	IPM-compatible pesticides
		Semio-chemicals
		Bt
		Resistant varieties
Late season	Sucking pests	Rational pesticide use in early season