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Pest resistance management strategies: A mini review of the case of cotton (*Gossypium hirsutum*) in Zimbabwe.

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Abstract

Cotton is an important cash crop for the Zimbabwe's smallholder sector but it is attacked by numerous pests that need to be managed. The economic method of cotton pest control is- integrated pest management that reduces the risk of resistance development to pests. This involves rotation of bollworm insecticides within the season, closed season for pink bollworm control, acaricide rotation scheme for sustainable red spider mite control. The land reform programme brought new farmers in the industry and new players in the agrochemical industry who are not aware of the integrated pest resistance management that delay resistance development in the cotton industry. This has been caused by shortage of chemicals in the market and collapse of some of the institutions which used to be custodians of the resistance management programme.

Key words: cotton, closed season, pesticide rotation, pest resistance management

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1. INTRODUCTION

Cotton is one of the major crops grown for commercial purposes in both communal and commercial lands in Zimbabwe (Maiyaki, 2010). Cotton is primarily grown as a fibre crop, but after the lint is removed by ginning, the seed can be crushed to provide vegetable oil and protein rich animal feed (Matthews, 1989). The crop is important for the maintenance of rural social and economic livelihoods, ensuring food security and generation of income (Mahofa, 2007). Zimbabwe used to produce high quality cotton, which, because it was contamination-free, was on high demand by both domestic and export market (Jowah, 1994). In Zimbabwe, cotton used to be called the 'white gold' for small scale farmers as it is their main cash crop. The crop is subject to attack from the time the seed is planted until picking (Tibugari, 2007). Insect pests can cause considerable damage so farmers need to treat with insecticides as an insurance against crop loss. Excessive chemical treatment may increase selection for resistance, so every effort is needed to minimise the number of pesticide applications. Expenditure on pest control is often a highly significant part of the total production costs so farmers need to decide when a particular control strategy is going to be cost effective (Tibugari et al., 2012).

Resistance is a heritable change in the sensitivity of the pest population that is reflected in the failure of a product to achieve expected level of control when used according to label recommendation for that pest species (IRAC, 2003). Resistance develops when a pest population develops the ability to tolerate a control tactic requiring the use of an alternative tactic if the pest is to be controlled. The development of resistance can be traced to the genetic variability that occurs in a population of living organisms. When a selection pressure such as pesticide application is imposed on a population, those individuals with the genotype best adapted to survive and reproduce despite the stress will increase and those that cannot tolerate the stress will decrease in frequency. Although several genotypes are present in a population at any one time the best adapted genotype assume numerical dominance (Pedigo, 2003). Entomologists have developed resistance management strategies which involve tactics for reducing the selection pressure. According to Norris et al. (2004), the tactics involve monitoring presence of resistant biotypes, modification of pesticide usage, and use of a combination of tactics, rotation and preservation of susceptible genes. Some of these tactics have been incorporated in Zimbabwe's cotton pest resistance management strategies. Successful implementation of such programmes involves various stakeholders including: the pesticide industry, farmers, extension agents, researchers and policy-makers. An integrated resistance management strategy which includes a closed season, alternation of insecticides within the season, chemical control and the acaricide rotation scheme was introduced in Zimbabwe to limit resistance development (Tibugari et al., 2012).

Prior to the land reform programme, cotton pest resistance management strategies were strictly observed by farmers, agrochemical industry and government. No cases of cotton pest resistance were reported after its introduction and that was attributed to its usage. After the land reform programme new farmers came into cotton growing because land was more accessible. Most of these new farmers are not aware of the cotton pest resistance management strategies; some may know them as practices enforced by cotton companies, researchers and extension agents without appreciating them as sustainable strategies for the industry as a whole. The collapse of the Cotton Training Centre in Kadoma, which used to train both farmers and extension agents may have exacerbated the situation. This paper therefore seeks to take stock of the strategies used in cotton pest resistance management in Zimbabwe and review the current situation.

2. Resistance management strategies in Zimbabwe

2.1 Recommended Insecticides for bollworm control

The recommended method of bollworm control in Zimbabwe involves the use of insecticides with spray timing based on egg counts (Brettell, 1997). Contact insecticides are used to control the two major bollworms which are *Heliothis armigera* and *Diparopsis castanea*. Chemically, the insecticides are divided into three groups as illustrated in Table 1. Organochlorines control the African bollworm while carbamates and pyrethroids can control both the red and African bollworms.

2.2 Alternation of bollworm insecticides

In order to delay the development of resistance, especially to the pyrethroids, the organochlorine and carbamate groups of insecticides are alternated with the pyrethroids within each cotton season (Brettell, 1986; 1997). In all areas of the country, except the south-eastern Lowveld, organochlorines/carbamates are used from crop emergence to the end of January while pyrethroids are recommended from the 1st of February to the end of the season. In the Lowveld, organochlorines/carbamates are used from emergence up to 25 December and from end of February to the end of the season. Pyrethroids are used from 25 December to 28 February for mid-season pest control. The idea is to limit exposure of bollworm populations to groups of insecticides for a maximum of three larval or feeding generations (Brettell, 1983). This takes about nine weeks at normal summer temperature. The use of pyrethroids is confined to the main flowering and boll-setting period and delaying the commencement of spraying with pyrethroids that are broad-spectrum insecticides is meant to avoid the early elimination of beneficial insects and aid natural control.

The restricted use of pyrethroids is not legally enforced but is a voluntary agreement between Government agencies, pesticide companies and farmers (Brettell, 1986). Since there have been no instances yet in Zimbabwe of bollworm or any other cotton pests developing tolerance (Tibugari et al., 2012), let alone resistance to pyrethroids, there is confidence that the strategy of within season alternation of these chemicals with organochlorines and carbamates works

Table 1. Insecticides used to control the cotton bollworms (*Heliothis armigera, Diparopsis castenea, Pectinophora gossypiella, Earis biplaga*) in Zimbabwe

Common Name	Trade Name	Chemical Group
Endosulfan	Thiodan/Thionex/Thioflow	Organochlorine
Carbaryl	Carbaryl/Sevin	Carbamate
Thiodicarb	Larvin/Carvin	
Fenvalerate	Fenvalerate/Agrithrin/Sanvalerate	
Flucythrinate	Cybolt	
Fluvalinate	Mavrik	Pyrethroid
lambdacyhalothrin	Karate	
Cyfluthrin	Talstar	

(Source: CCGA, 1998)

2.3 Ineffectiveness of insecticides against the pink bollworm (Pectinophora gossypiella)

The first instar larvae bore into young bolls almost immediately after hatching, making them difficult to kill with contact insecticides (Noble, 1969; Prentice, 1972). When they enter the young bolls, they feed for 10 to 15 days and complete their development inside a single boll and never move to a second one for feeding, thus further reducing chances of them coming into contact with insecticides. This raises the need for alternative non-chemical control methods.

2.4 The closed season

A closed season (Table 2) during which no cotton is allowed to grow, is a recognised means of reducing pink bollworm carryover between crops (Ingram, 1980) since this is a polyphagous pest. In other words, chemical control of the pink bollworm is difficult to achieve and therefore not recommended in Zimbabwe, although some control may be achieved when spraying for other bollworms.

Table 2. Legislated dead period for the control of the pink bollworm in Zimbabwe

Area	Latest date for slashing plants	Latest date for complete destruction	Earliest date for sowing cotton
Middleveld	August 15	September 10	October 20
Lowveld	August 1	August 15	October 5

(Source: Jowah and Mubvuta, 1993)

Besides the 'dead period' being the most effective and least expensive method available for the control of the pink bollworm, it reduces the possibility of carrying over other insect pests from one season to the other.

3. Cotton Aphid

3.1 Biological Control

The history of biological control of aphids in the open field was reviewed by Carver (1989) and Hughes (1989). The method of biological control practiced in the past and currently is that of conserving natural enemies (Hågvar and Hofsvang, 1991).

The first approach that was tried in the conservation of natural enemies was the use of selective aphicides early in the season. Reluctance by the farmers to use selective aphicides led to the Cotton Research Institute to investigate the number of beneficial insects needed to maintain pests below action levels. An average of three to four of the combined predator numbers (adult and larval coccinellids and spiders) per plant was shown to be the inaction level. However, records so far show that such an inaction level is only of use in a drought season where these predators are likely to reach or exceed this level (Tibugari et al., 2012)..

3.2 Chemical Control

Aphicides currently recommended for aphid control are presented in Table 3.

Table 3. Aphicides currently recommended for use on cotton in Zimbabwe

Common Name	Trade Name	Formulation	Active ingredient (a.i) g/ha
Dimethoate	Dimethoate	40 EC	100
Carbosulfan	Marshal	25 EC	88
Benfuracarb	Oncol/Shasha	20 EC	100
	Benfran	30 EC	100
Acetamiprid	Mospilan	20 EC	10

(Source: CCGA, 1998)

All the currently recommended aphicides have contact, systemic or translaminar action and they are all lethal to predators found in cotton fields because they have broad-spectrum action.

4. Red Spider Mites

4.1 Resurgence

Red spider mites are pesticide-induced pests of cotton (Duncombe, 1975; Penman and Chapman, 1988). In Zimbabwe they attained pest status after sustained use of broad-spectrum insecticides such as DDT to control *H. armigera* during the late 1950s and early 1960s. They first arose as secondary pest outbreaks as a result of the destruction of their natural enemies.

4.2 Resistance

Following the advent of the red spider mite as a major pest of cotton, dimethoate was recommended for its control in 1961 (Brettell, 1986). By 1968, red spider mites had developed resistance to dimethoate and closely related organophosphates such as demeton-S-methyl and thiometon.

Resistance in red spider mites is caused by over-exposure to chemical stress. The other factor is that there is a short generation turnover time, which is coupled with high fecundity (Matthews, 1989). More than 15 eggs per female can be laid per day at peak laying period and the life cycle can be as short as eight days in hot dry weather. Resistance is stable because of restricted mite population migration. Inbreeding is encouraged with little dilution from susceptible strains. Also, there is general incompatibility between mite species. Inter-specific hybrids produce sterile eggs. Finally, the pests exhibit arrhenotokous reproduction whereby a resistant population can arise from a single resistant unfertilized female initially producing male progeny pathernogenically that fertilize her to produce males and females.

There is therefore need to rely on acaricides for the foreseeable future, as no suitable effective biological control methods are applicable.

4.3 The acaricide rotation scheme

Early signs that red spider mite was becoming a problem due to widespread use of insecticides on cotton and resistance to dimethoate led researchers to develop and introduce the acaricide rotation scheme in the 1973/74 season (Duncombe, 1973). In the scheme, registered systemic or translaminar acaricides are classified into three distinct chemical groups among which cross-resistance is not likely to occur. Zimbabwe was divided into three regions (Figure 1) each with an equal area of cotton production (Brettell, 1986).

Figure 1. Map of Zimbabwe showing the three acaricide rotation regions

Each rotation area uses one chemical group of acaricides for two successive seasons then changes onto another group (Table 4). The rotation scheme is not legally enforced but because the need to contain further resistance development has been realized by both farmers and pesticide distributors, the scheme has worked successfully and no new instances of resistance have developed.

4.4 Present status

Currently the cotton industry has been invaded by many unscrupulous players whose major interests is profit-making without considering the sustainability of the industry as a whole. The companies operate on input credit schemes with the farmers and they distribute the pesticides to farmers without considering the implications on pest resistance development. The new farmers who acquired land through the land reform may not be aware of resistance management strategies that have prevented resistance development. The collapse of the Cotton Training Centre in Kadoma which used to be the centre of excellence in training farmers and extension personnel, could have worsened the scenario. The industry needs revival if resistance development is to be prevented.

Table 4. The acaricide rotation scheme in Zimbabwe

Seasons	Organophosphate group	Formamidine group	Organosulfur (Diphenyl) group
	Triazophos, Monocrotophos, Profenophos	*Amitraz, Chlorfenapyr*	*Tetradifon*
2003/04 and 2004/05	Western, Lowveld and Eastern areas.	Mazowe Valley and North-eastern areas.	Central and North-western areas.
2005/06 and 2006/07	Central and North-western areas.	Western, Lowveld and Eastern areas.	Mazowe Valley and North-eastern areas.
2007/08 and 2008/09	Mazowe Valley and North-eastern areas.	Central and North-western areas.	Western, Lowveld and Eastern areas

(Source: Adapted from Jowah and Mubvuta, 1993)

5. CONCLUSION

The pest resistance management is integral to the sustainability of the cotton industry in Zimbabwe. Collapse of the programme will lead to subsequent collapse of the industry. Intensive training is needed to conscientise the farmers of the importance of resistance prevention. The agrochemical industry, the various government departments and the farmer organisations need to work together to develop a way forward. If the situation is not attended to and farmers continue to use the same pesticides season after season, the pests will certainly develop resistance.

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