The Israel Cotton IPM-IRM Strategy–Retrospect and Prospect

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ABSTRACT

The Israeli IPM-IRM strategy, introduced in cotton in 1987, is focused primarily on controlling the whitefly, Bemisia tabaci. These and other cotton pests are controlled with novel insecticides and alternative control measures such as sex disruption against the pink bollworm (Pectinophora gossypiella), and by natural enemy encouragement. A rotation scheme in which each insecticide is used once during one pest-generation, followed by alternation with another insecticide with a different mode of action, has been established. Extensive resistance monitoring programmes are conducted. Baseline bioassays for susceptibility of key pests to the most important novel insecticides were carried out prior to the resistance monitoring in field populations. The rational use of insecticides has resulted in maintaining the susceptibility of the pests to the various groups of insecticides and substantially reduced insecticide applications. After 11 years of the IPM-IRM strategy, changes in the susceptibility to some conventional and novel insecticides have been observed. Modifications to the strategy that includes Bt transgenic cotton are being considered.

Introduction

Cotton is grown in Israel in the summer, from April to October. This season is dry season when all cotton fields are irrigated, mostly with a drip system. Approximately 70% of the cotton area is *Gossypium hirsutum* (L.) and 30% is *G. barbadense* (L.).

Since the 1950s, cotton growing has required many pesticide applications. In the mid-1980s, the efficacy of insecticides for controlling *Bemisia tabaci* (Gennadius) and *Spodoptera littoralis* (Boisduval) declined gradually, resulting in increasing numbers of applications and a risk to the economic viability of the crop (Forer, 1990). Consequently in 1987, an insecticide resistance management (IRM) strategy was established. The main purpose of the strategy has been to combat resistance to currently available and effective common insecticides by restricting their use to prolong the life span of new insecticides and to preserve the activity of natural enemies. In the 1990s, insecticides with novel activities, such as, buprofezin, pyriproxyfen, diafenthiuron and acetamiprid for controlling the whitefly and benzoylphenyl ureas (BPUs) for controlling *S. littoralis* were introduced in cotton and other crops. In the IRM strategy, the use of each of these compounds was limited to one pest generation (about 1 month). Long-term monitoring has accompanied the implementation of the strategy.

The Israeli cotton strategy is considered a national IRM success because the susceptibility of the pests to most groups of insecticides has been maintained and the rational use of pesticides has resulted in substantially reduced insecticide applications (Denholm and Rowland, 1992). However, after 11 years of the IPM-IRM strategy, changes in the susceptibility to some conventional and novel insecticides have been observed. This paper reviews this cotton IRM strategy in retrospect and prospect.

Cotton Pests in Israel

Many species of arthropods are present in cotton fields in Israel (Freidberg *et al.*, 1990). Two species are considered as key pests, the whitefly, *B. tabaci* and the pink bollworm (PBW), *Pectinophora gossypiella* (Saunders). While another four species, the cotton bollworm, *Helicoverpa armigera* (Hübner), the Egyptian cotton leafworm, *S. littoralis*, the spiny bollworm, *Earias insulana* Boisduval and the cotton aphid, *Aphis gossypii* (Glover) may build up to key pest status in some seasons. Some secondary pests such as spider mites are treated locally as required.

Bemisia tabaci

Bemisia populations develop in Israeli cotton fields mainly from July to September (Horowitz, 1986, 1993). High population levels may considerably reduce cotton yield (Forer, 1990). However, the heavy secretion of honeydew on the lint that results in stickiness, causes the most serious economic damage to cotton. This, in turn, interferes with the spinning process and reduces the fiber quality. Black sooty moulds that develop on the honeydew cause additional damage by staining the lint.

The whitefly is controlled with insect growth regulators (IGRs) such as buprofezin and pyriproxyfen and chloronicotinyls such as acetamiprid and imidacloprid. The treatments are based on a leaf-nymphs-count thresholds during July and August (Forer, 1990, Horowitz *et al.*, 1994). Conventional insecticides such as endosulfan and bifenthrin, are also

used as complementary measures late in the growing cotton season (Horowitz, 1993).

Pectinophora gossypiella

From late August through the autumn, the large larvae of the PBW gradually enter diapause and overwinter inside cotton seeds and plant residues on the ground. In the spring, they pupate and the emerged moths establish the first generation in cotton. Early attack damages the squares or the flowers; however, females favour oviposition on developed bolls. Eggs hatch in a few days and first instar larvae penetrate the bolls and destroy the seeds. Shredding the cotton stalks with prompt plough down after harvest and before the winter is an important cultural method of controlling most overwintering larvae. In the eastern valleys where the PBW populations establish early in the season and in other areas (ca 40 % of all plantations) the first control action is mating disruption, using sex pheromones "ropes" incorporated into twist tie dispensers. In midsummer, control is based on insecticide treatments, mainly organophosphates (OPs) and pyrethroids. Pheromone traps are used to determine the intervention thresholds for chemical PWB control.

The Israeli IPM-IRM Programs

Establishing the strategy - 1987-1988

Until the mid 1980s, the control of cotton pests was based exclusively on such conventional insecticides as organophosphates, carbamates and pyrethroids. Cotton growers used an average of 16 applications per season to obtain efficient control (Forer, 1990). As a result of ineffective pest control (especially of *B. tabaci*) in the mid-1980s, it was decided to develop an Integrated Pest Management/Integrated Resistance Management (IPM/IRM) strategy. The main goal was to delay the onset of resistance by using insecticides in a rational way. The tactics used were to restrict the use of conventional insecticides, such as endosulfan and pyrethroids, to a short period during the cotton season and to preserve beneficial arthropods during the early season (May-July) by reducing chemical treatments to minimum. The growing season was divided into four periods, with specific insecticide groups being allocated to each period. Insecticides with different modes of action were used in rotation, the period for each being based on the duration of the generation (approximately one month) of the relevant pests (Forer, 1990; Horowitz *et al.*, 1994, 1995).

1988-1996

In 1988, an extremely high population of whiteflies developed earlier than in previous seasons and resulted in a considerably reduced cotton yield (Forer, 1990). As the conventional insecticides were inadequate in preventing damage to the crops, buprofezin, pyriproxyfen and diafenthiuron were registered (Horowitz *et al.*, 1994). The introduction of these new products, particularly IGRs, resulted in effective control, as these insecticides are considered selective for key cotton pests such as *B. tabaci* and *S. littoralis* (Ishaaya and Horowitz, 1998).

In the 1989-1990 seasons, buprofezin was the principal compound for controlling the whitefly; however, from 1991 until the present, the practice has been to treat the July attack of *Bemisia* with pyriproxyfen. In most fields, one treatment with pyriproxyfen at mid-July is sufficient to control whiteflies until the end of the season. However, if an additional treatment is required, buprofezin is recommended (Horowitz, 1993).

An achievement of this strategy is the reduction of insecticide applications against the entire range of cotton pests, especially against *Bemisia*. Acceptance of a rational pest management control program by the cotton growers and the use of novel insecticides with selectivity for cotton pests were essential in achieving the reduction in insecticide use (Figure 1).

1997-1998

The strategy was change (Table 1) due to the high levels of resistance to pyriproxyfen in *B. tabaci* observed in some cotton fields, especially in Ayalon Valley (Figure 2). Fortunately, the introduction and registration of the chloronicotinyl group (acetamiprid and imidacloprid) have replaced pyriproxyfen applications in the resistant areas.

Prospect

The Israeli IPM-IRM strategy is a unique attempt at combating resistance to insecticides in the complex array of cotton pests. Eleven years into the IRM strategy, changes in the resistance situation toward the conventional and novel insecticides have been observed. An IRM strategy is generally not capable of preventing resistance to insecticides, but can delay the onset of resistance or "buy time" until new compounds are available (Forrester, personal communication). Thus, new insecticides are being assayed against whiteflies and lepidopteran pests if resistance develops in *B. tabaci* to the novel IGRs and/or if the benzoylphenyl ureas lose their efficacy against *S. littoralis*.

One problem with the current Israeli strategy arises from the obligatory use of non-selective insecticides for controlling the PBW and spiny bollworm in midsummer. These insecticides interfere with the ecological balance, they are harmful to beneficial arthropods and they may cause a build up of earlier attacks by other pests (such as *B. tabaci*). A strategy incorporating *Bt*-transgenic cotton plants should, therefore, be considered to replace non-selective insecticides in controlling bollworms such as PBW and *E. insulana* without harming natural enemies. This could benefit the Israeli IPM-IRM strategy.

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Table 1. Israeli cotton IPM-IRM program for 1998.

Period	I		II		III		IV	
	April	Mid-May	Mid-May	Mid-Jun	Mid-July	Mid Aug	Mid Aug	Mid Srpt
	Aphids		*Helicoverpa armigera*		*Bemesia tabaci* →			
	Cutworm				*Pectinophora gossylielle* (PBW →			
					Earias insulana →			
					Spodoptera litoralis			
Pesticides	-		Endosulphan*		Pyriprorefon**		Buprofezin**	
					Acetamiprid**		Diafenthiuron**	
					Imidacloprin**			
							BPUs***	
							Teflubenzuron	
					Pyrethroids		Chlorfluazuron	
							Lufenuron	
					OPs and Carbamates		OPs and Carbamates	
			Mating disruption (sex pheromone of PBW)					

Figure 1. Number of insecticide applications per cotton season. WF - treatments against *Bemisia tabaci*; Total - treatments against all the pests.

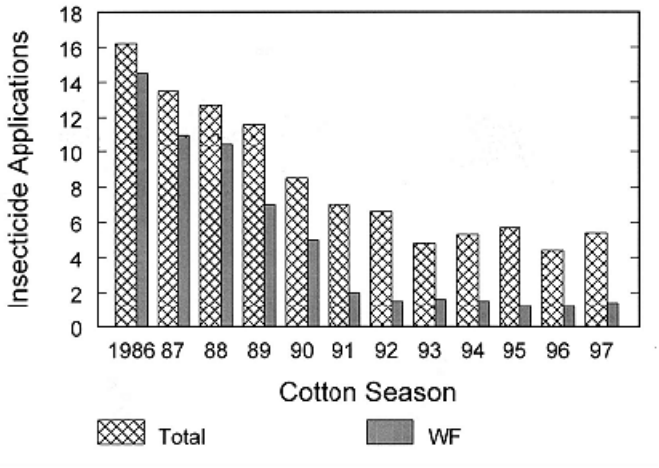

Figure 2. Log concentration-response curves (on a probit scale) of the effect of pyriproxyfen on *Bemisia tabaci* populations collected in early 1991 to 1997 cotton growing seasons (prior to pyriproxyfen treatment) in cotton fields in western Negev (A) and Ayalon Valley (B) of Israel. In the 1995 early-season monitoring, high resistance to pyriproxyfen was observed in the Ayalon Valley.