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BACILLUS THURINGIENSIS AND COTTON SEED OIL AS CONTROL AGENTS IN AN INTEGRATED PEST MANAGEMENT PROGRAM FOR COTTON IN ISRAEL

M. BROZA,[1] G.D. BUTLER,[2] A. VENETIAN,[1] AND A. SHAVTT[1]
[1]University of Haifa, Oranim, K. Tivon 36910,
Israel and Becker Microbial Products [Israel] Inc., Israel
[2]Western Cotton Research Laboratory, U.S. Department of Agriculture,
4135 E: Broadway, Phoenix, AZ 85040, U.S.A.

ABSTRACT

Eight to ten [but in some years up to 18] chemical insecticide applications are generally needed to suppress insect pest populations in cotton during the season, in Israel. The heavy use of chemicals has caused development of resistance in the target insect populations and a serious impact on human health and the general ecology of the cotton growing area.

An integrated pest management program (I.P.M.) was implemented in four commercial plots in the northern valleys of Israel, each ten to 17 acres in size. The program includes the following elements:

1. Bacillus thuringiensis var. kurstaki to control Heliothis armigera and Earias insulana.

2.. *B. thuringiensis var. aizawai or entomocidus proposed to control Spodoptera littoralis.*

3. Crude cotton seed oil combined with the soil insecticide, aldicarb, applied to control *Aphis gossypii* and *Bemisia tabaci.*

4. Disruption pheromone applied on early season populations of the pink bollworm *Pectinophora gossypiella.*

5. Only two to three aerial applications of chemical insecticides were used in the program late in the season. This shift was too late to prevent damage to the bolls by the Earias population. The number of application was higher [1-3] in the IPM plot, and more expensive. In one out of the four plots a 20% reduction in yield was measured, which is unacceptable economically, but elements of this program should be reconsidered in future trials.

INTRODUCTION

Cotton is grown on more than 70 million acres in some 80 countries throughout the world. In all areas in the world there are major insect pest problems, and at the present time, control in most areas depends on the heavy use of chemical insecticides. Although the development of pesticide resistance causes the onset of the "crisis phase" in cotton production (Doutt and Smith, 1971), the world market of insecticides used in cotton continued to increase (by 122%) during the years 1971-1978 (Cooke and Parvin, 1983).

In the USA, cotton absorbed 45% of the total insecticides applied to field crops, but lately some new integrated pest programs were established there; and in some areas, like the Central Valley of California, cotton is now largely produced without the use of pesticides at all (Phillips et al., 1980). In Israel cotton absorbs more than 55% of the total insecticide consumption for crop protection. Because of the intensive nature of Israeli agriculture and the lack of cultivated land, cotton fields are cultivated sometimes close to neighboring farm houses, fishponds and orchards. Thus, the chemical insecticides used often exercise a direct influence on human health and the whole environment.

In the program presented here, an effort was made to construct a program using non-chemical alternatives, both to moth and sucking insects. The six major cotton pests in Israel and their non-chemical control agents, as proposed here, are shown in Table 1. At least five other minor pests should be listed here: The noctuids *Agrotis segetum* Schiff and *Spodoptera exigua* Hon, the sweet potato leaf hopper *Empoasca lybica* Berg, *Thrips tabaci* Lind and two mites of the genus *Tetrancychus*

More detailed information about the use of crude cotton-seed oils to control whiteflies and aphids will be given elsewhere.

TABLE 1
The six major pests of cotton fields in Israel and the alternative control methods

Major pest	Years of heavy outbreaks 1968–1987	Mean no. of conventional treatments/season		Non-chemical control method
		Beth-Shean	Zevulun	
Heliothis armigera Hb	1984–5	0.5	2	B.t. kurstaki[1]
Earias insulana Boisd.	serious pest every year	>4	1–2	B.t. kurstaki[2]
Pectinophora gossypiella Saun.	1970–1; 1982–3	3	0	Disrupt. pheromone[3]
Spodoptera littoralis Bois.	1968, 1979	4	4	B.t. entomocidus[4]; B.t. aizawai[4]
Bemisia tabaci Genn.	1976–1987	>7	>7	C.C.S.O.[2,5]
Aphis gossypii Glo.	1984	0.3	2	C.C.S.O.[2]

[1]Broza, 1986 and present study.
[2]Present study.
[3]R. Or et al. (1986).
[4]Broza et al., 1984, and unpublished.
[5]C.C.S.O. — Crude cotton seed oil with emulsifier (10%).

MATERIALS AND METHODS

Four commercial fields were used for testing the program, as listed in Table 5. Field number one is located in the Valley of Zevulun [Kibbutz Yagur]. All others, in the Valley Beth She'an [Plot No. 4 — Sede Eliaha'u, plots 2 and 3 in Ma'oz Chaim]. Plots 2 and 3 were aerially sprayed with a Thrush Commander plane equipped with a Swath Master spreader [Transland USA] with a spray volume of 50 liters/ha. The other two plots were sprayed with a ground-inflatable sleeve booms sprayer at a volume of 120 liters/ha. Oil experiments (Table 2 and Fig. 1) were carried out with the ground sprayer only. The ground boom sprayer was 18 meters long and fitted with 70–×3 nozzles at 25 cm intervals. A large fan provided an air blast of 35 m/sec through holes in the inflatable sleeve along the boom above each nozzle. This assisted in directing spray to the undersides of the leaves.

The microbial insecticide used was Bio-T, a liquid concentrate of *Bacillus thuringiensis* var. *kurstaki* produced by Becker Microbial Products (Israel) with a potency of 8000 I.U./mg. Five liters per hectare were applied in each treatment using crude cotton seed oil (2.5%) as spreader and protectant. In special oil treatments against aphids and whiteflies, 5% of oil was used. The crude oil contained 10% emulsifier.

Field counts of both adults and nymphs of aphids were made on the first fully expanded leaf with the aid of a head magnifier (× 10). Adult whiteflies were sampled with a beating technique (Butler et al., 1988). A sample consisted of the collection of whiteflies from 10 plants [five only when adults were very abundant], and 12 samples were taken per treatment.

RESULTS AND DISCUSSION

Control of homopteran pests

In a previous publication (Butler, Hutchison and Broza, 1988) we demonstrated that the soil insecticide — aldicarb — can be used as a control agent against sucking insects in cotton and by doing so, reduces foliar chemical spray and kills off beneficial insects in a program in which lepidopteran pests may be partially controlled by *B.t.* preparation. However, aldicarb is a very toxic product and it cannot be applied later than sixty days before harvest. [It is a well-known phenomenon that immediately after aldicarb influence has terminated, a real outbreak of whiteflies may occur at a time when bolls are open and whitefly honeydew can spoil the lint.] In the present research we tested the use of crude cotton seed oil as a complementary agent for the control of aphids and whiteflies. Some preliminary results of this research will be given here.

Aphids and leafhopper control

In 1987, infestation of cotton fields by aphids was low and it occurred in only one of our plots [No. 1 in Table 5] immediately after germination and again toward the end of the growing season. Two consecutive treatments with crude cotton seed oil [C.C.S.O.] were needed to suppress the light early aphid population. Patches of heavy infestation of aphids occurred in some areas in this field toward the end of the season (August 15) and it was reduced by C.C.S.O., as shown by the results given in Table 2.

Data on the occurrence of the sweet potato leafhopper, *Empoasca lybica* in the same field, at the time of application, indicate that oil did not affect its population size. Although the leafhopper population was quite high, it was not high enough to cause long term damage. But nevertheless, in the half non-aldicarb plot of the field, a natural epidemic of the entomofungi, *Eyrinia radicans* occurred on the *Empoasca* population. This epidemic was, in part, responsible for the *Empoasca* control. Chemical treatments of the same field could prevent the development of this natural biological agent.

Whitefly control

In plots No. 2 and 3, only aldicarb treatments were used to control the whitefly populations. The treatments were effective and left only a short period of time for the build-up of whitefly populations towards the date of defoliation. Their population was much lower in the IMP plots than in the adjacent

TABLE 2
Control of the aphid *Aphis gossypii* in cotton fields, with crude cottonseed oil = C.C.S.O. [Emeq Zevulun 14.8.87]

		No. of aphids/1 leaf[1]	
Treatment	Pre-treatment	Before treatment	After treatment[2]
C.C.S.O.	Non-	108	31
	aldicarb[3]	32	20
Untreated	Non-	84	153
	aldicarb[3]	40	65

[1]No. of aphids per one fully expended top leaf (x = 200)
[2]Six days after treatment.
[3]Pretreatment: Aldicarb (soil insecticide). Early Aldicarb during seeding.

commercial fields. The mean number of pupae per one fully expanded top leaf in plot 3 were 16.6 ±0.9 in the commercial field and only 10.5 ± 2.2 in the IMP field. Three hundred leaves were counted for each treatment [September 14].

In plots No. 1 and 4 strips of three alternative regimes were tested: (a) Early aldicarb + oil at the termination of the aldicarb effect; (b) Early aldicarb + chemical insecticide; and (c) Crude cotton seed oil throughout the season of the build-up of the whiteflies. The results of one of the plots are given in Figure 1.

We demonstrated that consecutive applications of crude cotton seed oil (every six to ten days) kept the whiteflies population under control. The results were even better when using oil after early aldicarb (Fig. 1). While in the chemical insecticide field, the population lowered by the treatment tended to increase manifold immediately thereafter (Fig. 1). The high population level of all treatments in the last counting coincides with the defoliation of all cotton fields in the area, a stage in which a rapid maturation of adults, caused the occurrence of regional clouds of whiteflies.

It is worthwhile mentioning that C.C.S.O. is a very cheap product and its use every few days is economically acceptable, especially when, in part of the applications, it will be added as a tank mix additive to *B.t.* preparations. Broza and Venetzian (in preparation) show that applying *B.t.* to alfalfa with C.C.S.O. as an adjuvant, increases the persistence of *B.t.* on the leaves by almost 100%. D. Gerling [unpublished] found in preliminary results, that C.C.S.O. did not reduce whitefly parasites although predators could be reduced by the non-selective insecticidal activity of oil (Womack et al., 1985).

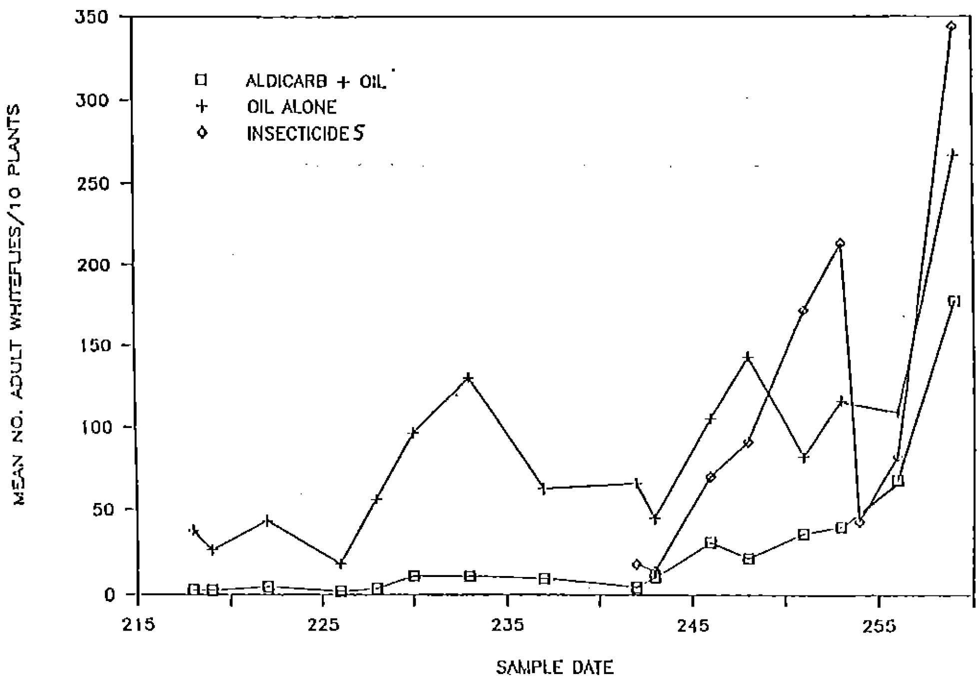

Fig. 1. Mean number of adult whiteflies during the season in a cotton plot treated with crude cotton seed oil and with oil after early aldicarb, as compared to a plot treated with foliar insecticide after early aldicarb.

Hellothis control

The option to control the *Heliothis armigera* population with *Bacillus thuringiensis* var. *kurstaki* has been demonstrated (Broza, 1986). Similar results have been achieved this season in nine different applications in the different plots. The results of one of them is given in Table 3. A typical result may cause 50–65% mortality only. However, early season Heliothis feeds mainly on squares and Sachs and Wallach (1984) demonstrated that cotton plants produce a surplus of squares, so partial reduction in bollworm population can be satisfactory since it will be reduced below the economic threshold.

TABLE 3
Control of *Heliothis armigera* with *B.t. kurstaki* preparation in comparison to standard chemical insecticides during cotton — early season in Emek Zevulun (19.6.87)

	Larvae per m row			Mean no. of squares/m row after 9 days
Treatment	Pretreatment counting	Four days after treatment	Nine days after treatment	
B.t. kurstaki	3.5	1.88	2.7	8.8
Endosulfan	4.1	0.93	1.0	10.3
Untreated control	3.2	2.86	4.3	5.8

Earlas control

The data presented here summarize the first field trials carried out to control the Spiny Bollworm, *Earias insulana* in cotton field in Israel, using a microbial agent. *B.t.* var. *kurstaki* was applied three times in each of the four plots studied in this project. An example of one of these applications is given in Table 4. The rate of control by *B.t.* was compared to the chemical treatment in the adjacent field and to an untreated population within a 200 sq. m. plot left in the middle of the "biological field." A meaningful reduction in *Earias* population treated with *B.t.* can be seen. However, at this stage (end of July), the *Earias* population was very high, so we shifted our program to use monochrotophos as the chemical alternatives. The loss of 20% of the yield in plot No. 3 (Table 5) is due to the insufficient control of the *Earias* population. The shift to monochrotophos should have taken place at an earlier stage.

TABLE 4
Control of spiny bollworm, *Earias insulana* with *B.t. kurstaki* preparation sprayed by an airplane, in comparison to standard chemical and untreated control plot. The heavy population at that point shifted the IPM program into using chemicals only (Beth-Shean 17.7.87)

	No. of larvae/1m row 5 days after treatment		
Treatment	Small larvae	Medium-size larvae	Big larvae
B.t. kurstaki	2.3	2.2	3.0
Monochrotophos	1.0	1.25	2.0
Untreated Control	5.88	6.33	4.0

TABLE 5
Summary of the whole season treatments applied to four commercial cotton fields, held under present IPM program, in contrast to four standard fields [Beth She'an, 1987]

Plot	Size acres	Cotton variety	No. *B.t.* treatments[a]	No. treat-ments with CCSO[b]	No. Chem. treatments	Yield[c]	Chem. control plots	
							No. treatments	Yield[c]
1	10	Akala Sj2	8+CCSO	+4	3	1588	13	1572
2	12	Akala Sj2	7+CCSO		2	1652	7	1600
3	17	Pima F27	6+CCSO		3	1348	8	1780
4	11	Pima F27	5+CCSO	+2	2	1760	6	1720

[a]2.5% C.C.S.O. were added to tank mix formulation of *B.t.*
[b]5% C.C.S.O. only.
[c]Gross yield; kg/acre.

Control of pink bollworm

The larvae of the pink bollworm *Pectinophora gossipiella* penetrate the bolls immediately after hatching, so control with B.t. preparation is impractical (Broza, unpublished). However, a program for the use of disruptive pheromone was carried out in Beth Shean on a regional basis (Or et al., 1986). All our plots in Beth Shean [Plots no. 2–4] received two applications to suppress the low, early-season population.

The chemical-phase of bollworms control

During the last three weeks of boll maturation while many of them are still soft, build-up of populations of both the Spiny Bollworm and the Pink Bollworm reach a very high level. We turned to the use of powerful chemical insecticides. Two to three applications of monochrotophos or pyrithroids were applied to all four IPM plots. Consequently we succeeded in postponing the start of this phase and the amount of chemical used.

Control of the Egyptian cotton leafworm

The Egyptian Cotton Leafworm, *Spodoptera littoralis* is a late season pest in cotton fields in Israel. Very low leafworm populations were typical for the 1984–1987 seasons, so no special treatments against this pest were needed. The possible use of *B.t.* to control the Egyptian leafworm has been demonstrated in the past (Broza et al., 1984).

SUMMARY AND CONCLUSIONS

The whole program presented here cannot be justified for immediate use, in terms of the present net income of cotton in Israeli farming, since it relied on a greater number of treatments, more expensive pesticides, and a meaningful loss in one out of the four plots tested. However, programs such as those presented here should be tested again. Nevertheless, our observations could lead to the future use of nonchemical agents proposed here in the following:

(a) *B.t.* could be considered as a control agent of early season and low to moderate populations of *Heliothis armigera* and *Earias insulana.*

(b) Crude cotton seed oil could be used in combination with *B.t.*, both as protectant and spreader of *B.t.* preparation and as an agent reducing whitefly and aphid populations.

(c) The use of both elements mentioned above, together with disruptive pheromone for the Pink bollworm and shifting to chemical insecticides at the right time could create a feasible new I.P.M. program in the future.

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