MICROBIAL CONTROL OF *HELIOTHIS* SPP. (LEPIDOPTERA: NOCTUIDAE) IN COTTON: DOSAGE AND MANAGEMENT TRIALS[1]

M. R. Bell and C. L. Romine
Western Cotton Research Laboratory
USDA, ARS
Phoenix, AZ 85040
(Accepted for publication Feb. 25, 1985)

ABSTRACT

Cotton, *Gossypium hirsutum* (L.), infested with relatively low populations (untreated range: 0.3 - 0.7 larva/plant) of *Heliothis* spp. larvae was treated with varying mixtures of the nuclear polyhedrosis viruses from *Heliothis zea* or *Autographa california* (dosages: 2.97 and 5.93×10^{11} polyhedral inclusion bodies/ha) and the bacterium, *Bacillus thuringiensis* Berliner (dosages: 0.14 - 0.56 kg/ha of Thuricide®). The bacterium when mixed with a spray and adjuvant was as effective as a chemical standard in reducing plant damage and low populations of *Heliothis*. Applying mixtures of the viruses with the bacterium did not increase efficacy. In a commercial 16-ha field, four aerial applications of a microbial mixture of 150 g Elcar® and 560 g Thuricide plus 3.36 kg adjuvant resulted in a ca. 76% viral infection and sufficiently controlled the larval infestation and protected the fruit from damage. The *Heliothis* population in another 16-ha field was controlled using four applications of chemical insecticides. Natural viral disease prevalence was ca. 3%. Although *Heliothis* egg numbers ranged from ca. 20 - 80 eggs/100 plants in both fields during the test, boll damage in the microbially treated field was only 0.5% compared to 0.6% in the chemically treated field. Further, yields from both fields were ca. 3×10^3 kg/ha, indicated similar control.

Key Words: *Heliothis,* cotton, microbial control, nuclear polyhderosis virus, tobacco budworm, *Bacillus thuringiensis,* baculovirus.

J. Entomol. Sci. 20(2): 146-151 (April 1985)

INTRODUCTION

There are presently two insect pathogens available and registered for use in the control of insect pests on cotton, *Gossypium hirsutum* (L.): the nuclear polyhedrosis virus from *Heliothis* spp. (*H*NPV) and the bacterium, *Bacillus thuringiensis* Berliner *(B. thuringiensis* HD-1 isolate) *(Bt).* A third pathogen, the NPV from the alfalfa looper *(Autographa californica* Speyer), *(Ac*NPV), has also shown substantial promise for use against cotton pests, although not yet registered (Bell and Kanavel 1977; Vail et al. 1977; Bell and Romine 1980).

A mixture of 560 g Thuricide®, 7.41×10^{11} Polyhedral Inclusion Bodies (PIB) *Ac*NPV, and 3.46 kg of Coax®/ha, has provided commercially acceptable control of *Heliothis* spp. in cotton (Bell and Romine 1980). However, lower dosages also may provide adequate control. Furthermore, the microbials need to be evaluated in a larger field with standard agronomic methods, including aerial application methods. The tests reported herein were conducted in 1982 to evaluate the control of

[1] Mention of companies or commercial products does not imply recommendation or endorsement by the U. S. Department of Agriculture over others not mentioned.

Heliothis spp. with various microbial dosages and treatments in a small plot study and to evaluate aerially applied microbials on a larger, commercial field in Arizona.

MATERIALS AND METHODS

The screening test was conducted at the University of Arizona Cotton Research Center, Phoenix, AZ, on ca. 0.015 ha plots of "Deltapine 70" variety of short-staple cotton grown by standard agronomic practices. The treatments were various combinations of *Ac*NPV, *H*NPV (Elcar®), *Bt* (Thuricide®) and the feeding adjuvant Coax, with Pydrin® as an insecticidal standard. The *Ac*NPV was produced by methods described by Vail et al (1971). The 14 treatments, including an untreated control, were replicated four times and arranged in a randomized complete block design. All treatments were applied with a high-clearance sprayer in a total volume of 93.5 liters of water/ha on 21, 30 Aug. and on 7, 19, 24 Sept. During this same period, five applications of carbaryl at 2.25 kg AI/ha were applied to reduce the population of the pink bollworm, *Pectinophora gossypiella* (Saunders).

Treatments were evaluated by examining 10 random plants in each plot on 20, 27 Aug. and 3, 15, 29 Sept. and recording the number of *Heliothis* spp. eggs and larvae, number of fruiting bodies, and damage to the plant terminal and fruit. Data were subjected to analysis of variance and treatments means were compared by LSD (Steel and Torrie 1960).

A second test was conducted on a 16 ha commercial field of late-planted short-staple cotton located near Chandler, AZ. This field was monitored for *Heliothis* spp. eggs and larvae in plant terminals and treated when thresholds were exceeded. Control treatments commenced on 19 Aug., with subsequent treatments on 31 Aug., 9, 14 Sept. All treatments consisted of 0.56 kg of Thuricide, 5.93×10^{11} PIB of *H*NPV (150 g Elcar®), and 3.36 kg of Coax/ha suspended in 47 liters of water/ha and were applied by standard aerial application with fixed-wing aircraft. The field had a single treatment of Orthene® on 19 Aug., at a rate of 0.9 kg AI/ha to control lygus bugs, and No-Mate® at 30 g (2.3 g AI/ha) on 31 Aug. to control pink bollworms.

Treatment effectiveness was evaluated by monitoring the immature *Heliothis* spp. population and plant damage. At weekly intervals, 200 randomly selected plants were examined for the total numbers of eggs and larvae in terminals and percentage of the terminals and fruits damaged. In addition, larvae were collected on 8, 13 Sept., placed individually on artificial diet and examined for viral infection to indicate disease prevalence.

Since this test had neither replications nor an untreated control, no statistical comparisons were made. However, a general comparison of control was made to that obtained in a companion 16-ha field located ca. 3 km away and planted by the same grower on a similar planting date. Insecticides were applied 4, 19, 31 Aug., and 10 Sept. for control of *Heliothis* spp., pink bollworm, or lygus. The insecticides and their application rates were: Orthene, 1 kg AI/ha; Fundal®, 0.95 kg AI/ha; and Pydrin, 0.5 kg AI/ha.

RESULTS AND DISCUSSION

Heliothis spp. larval infestations were low in the screening test and did not cause severe crop damage. Prior to the 1st application (20 Aug.), we found an average of 7.7 *Heliothis* eggs/10 plants. One week later, the number decreased to only 1.7 eggs/10 plants and continued to decline during the remainder of this test period. There were no differences found between the number of eggs within the treatment blocks, and 59 of the 60 eggs collected and reared on artificial diet were identified as tobacco budworm, *Heliothis virescens* (F.).

All treatments reduced the number of *Heliothis* larvae when compared to the untreated control (Table 1). Four of the *Ac*NPV + *Bt* + Coax treatments, a *Bt* +

Table 1. Effects of various microbial treatments on *Heliothis* in cotton, 1982*

Treatment	Rate (per ha)	Number of larvae/10 plants	% Terminal damage	% Boll damage	% Square damage
Untreated	—	5.8 a	29.6 a	8.7 a	14.5 a
HNPV	5.93×10^{11} PIB	3.8 bc	30.8 a	7.3 ab	10.8 ab
HNPV	5.93×10^{11} PIB	3.9 b	29.3 a	7.7 ab	11.0 ab
+ *Bt*	0.56 kg				
HNPV	5.93×10^{11} PIB	2.4 cd	28.6 ab	5.8 bc	7.2 bcd
+ *Bt*	0.56 kg				
+ Coax	3.36 kg				
*Ac*NPV	2.97×10^{11} PIB	2.5 bcd	30.7 a	6.1 bc	8.2 bcd
+ *Bt*	0.14 kg				
+ Coax	3.36 kg				
*Ac*NPV	2.97×10^{11} PIB	2.3 d	30.5 a	6.0 bc	9.1 bc
+ *Bt*	0.19				
+ Coax	3.36 kg				
*Ac*NPV	2.97×10^{11} PIB	2.2 d	21.5 ab	5.8 bc	5.7 cd
+ *Bt*	0.28 kg				
+ Coax	3.36 kg				
*Ac*NPV	2.97×10^{11} PIB	1.5 d	26.0 ab	4.3 cd	4.6 d
+ *Bt*	0.56 kg				
+ Coax	3.36 kg				
*Ac*NPV	5.93×10^{11} PIB	2.8 bcd	21.4 ab	5.5 bc	6.6 bcd
+ Coax	3.36 kg				
*Ac*NPV	5.93×10^{11} PIB	2.1 d	22.7 ab	4.2 cd	7.8 bcd
+ *Bt*	0.56 kg				
+ Coax	3.36 kg				
*Ac*NPV	5.93×10^{11} PIB	2.8 bcd	28.5 ab	7.0 ab	8.6 bcd
+ *Bt*	0.56 kg				
Bt	0.56 kg	1.8 d	17.7 b	5.4 bcd	6.6 bcd
+ Coax	3.36 kg				
Pydrin	105 g	2.2 d	19.7 ab	4.2 cd	6.6 bcd
Pydrin	105 g	1.9 d	17.9 b	3.1 d	5.4 cd
+ Coax	3.36 kg				
	LSD =	1.46	1.63	2.38	4.41

* Average of 10 plants/replicate and 4 replicates/treatment over a 4 wk period (27 Aug. - 29 Sept.). Data followed by the same letter are not significantly different at the 0.05% level (LSD).

Coax treatment, and the Pydrin treatments were significantly ($P \leq 0.05$) better than the *H*NPV or *H*NPV + *BT* treatments in reducing the number of larvae present. As reported in other studies (Bell and Kanavel 1978; Luttrel et al. 1982), the addition of a spray adjuvant to the microbials tends to increase their effectiveness against *Heliothis*.

Only the *Bt* + Coax and the Pydrin treatments significantly ($P \leq 0.05$) reduced terminal damage as compared to the untreated plots (Table 1). Other treatments containing a similar dose of *Bt* mixed with NPV failed to reduce terminal damage. Some mixtures of NPV and *Bt* have been shown to be antagonistic in their effects on larval mortality (Young et al. 1980; Bell and Romine, unpublished data). In this present study, where boll damage never exceeded 14% in the control, there appears to be no advantage in using mixtures of these pathogens for controlling *Heliothis* damage. This observation can be misleading as there are several variables to be considered. The NPV, although capable of causing a high incidence of infection and eventual larval mortality, is relatively slow acting and its use alone usually results in crop loss. *Bt* has an arresting effect upon larval development (Dulmage et al. 1978), which may have considerable impact on crop protection. While *Bt* is relatively fast acting, normal field doses may not cause high mortality. In an earlier study (Bell and Romine 1980), a mixture of NPV + *Bt* + Coax resulted in superior control of *Heliothis* when compared to treatment with each microbial individually. With the heavy *Heliothis* densities experienced in that test combining the fast action of *Bt* to prevent crop damage with NPV for larval mortality and a feeding adjuvant to increase larval infection provided an acceptable level of crop protection. Further investigations are needed to study the many multi-faceted effects of these microbials upon larval development and to determine their potential in microbial control situations.

The number of *Heliothis* eggs and larvae on plant terminals and the estimation of fruit damage in the microbially treated field of the 2nd test are depicted in Figure 1. Of 75 *Heliothis* larvae collected at random and placed on artificial diet, 76% were infected with NPV, a disease prevalence similar to that obtained using ground application equipment. Throughout the test period, only 0.5% of the 14,182 bolls and 4.1% of the squares examined were damaged by *Heliothis*. In addition, 136 larvae were found on squares and only 9 were found on bolls. This larger proportion of larvae on squares indicates that most of the larvae were being killed before reaching the bolls. Since the microbials do not act as rapidly as do chemical insecticides, the number of young larvae found in the terminal area is usually not controlled by the microbials for the same reasons. The numbers of eggs found on plants in the chemically treated field were similar to those shown for the test field. However, due to the rapid removal of larvae by the insecticide treatments, they were more difficult to find than in the microbially treated field. Disease prevalence of natural *H*NPV in the chemical field was ca. 3%, (based on 48 larvae found) and fruit damage was similar to that in the microbially treated field (0.6% of the bolls and 2.1 of the squares damaged by *Heliothis* spp.). The yield from the microbially controlled field and the chemically controlled field were both estimated by the grower at ca. 3×10^3 kg/ha. Thus, we believe the microbial control achieved in this test offered an efficacious alternative to chemical control.

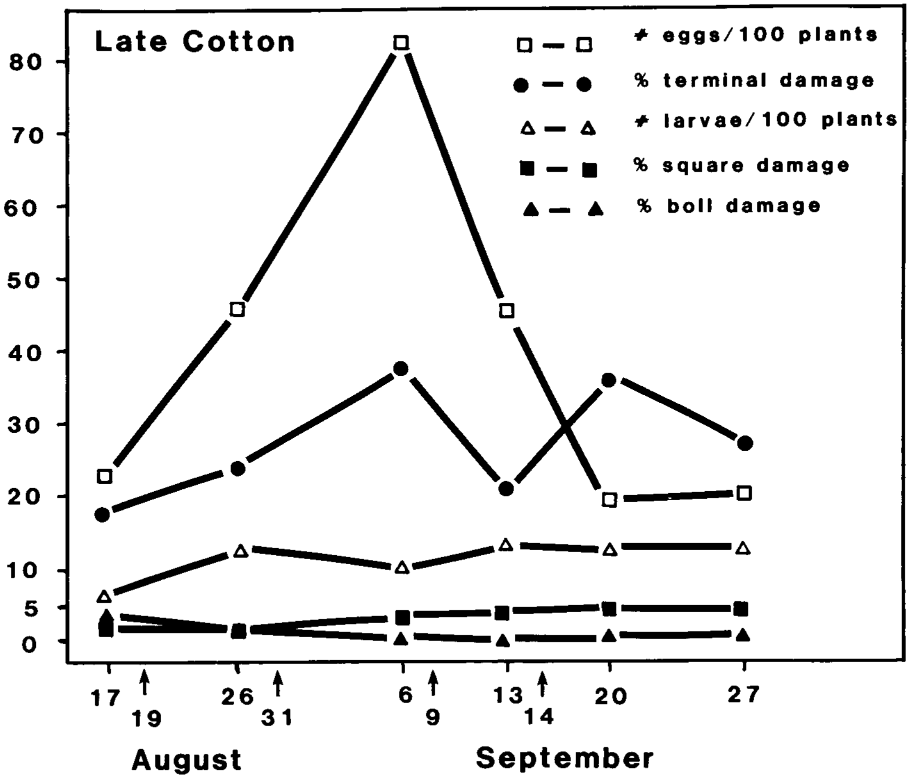

Fig. 1. *Heliothis* population and plant damage in late-planted cotton treated with *H*NPV, *Bt* and Coax®. Arrows indicate spray date.

ACKNOWLEDGMENT

We thank N. P. Curtice for her assistance in gathering and compiling the data.

LITERATURE CITED

Bell, M. R., and R. F. Kanavel. 1977. Field tests of a nuclear polyhedrosis virus in a bait formulation for control of pink bollworms and *Heliothis* spp. in cotton in Arizona. J. Econ. Entomol. 70: 625-9.

Bell, M. R., and R. F. Kanavel. 1978. Tobacco budworm: Develoment of a spray adjuvant to increase effectiveness of a nuclear polyhedrosis virus. J. Econ. Entomol. 71: 350-2.

Bell, M. R., and C. L. Romine. 1980. Tobacco budworm field evaluation of microbial control in cotton using *Bacillus thuringiensis* and a nuclear polyhedrosis virus with a feeding adjuvant. J. Econ. Entomol. 73: 427-30.

Dulmage, H. T., H. M. Graham, and E. Martinez. 1978. Interactions between the tobacco budworm, *Heliothis virescens*, and the endotoxin produced by the HD-1 isolate of *Bacillus thuringiensis* var. Kurstaki: Relationship between length of exposure to the toxin and survival. J. Invert. Path. 32: 40-50.

Luttrell, R. G., S. Y. Young, W. C. Yearian, and D. L. Horton. 1982. Evaluation of *Bacillus thuringiensis*-spray adjuvant-viral insecticide combinations against *Heliothis* spp. (Lepidoptera: Noctuidae). Environ. Entomol. 11: 783-7.

Steel, R. G. D., and J. H. Torrie. 1960. Principles and Procedures of statistics. McGraw-Hill Book Co., New York, NY.

Vail, P. V., T. Whitaker, H. Toba, and A. N. Kishaba. 1971. Field and cage tests with polyhedrosis viruses for control of the cabbage looper. J. Econ. Entomol. 64: 1132-6.

Vail, P. V., T. J. Henneberry, and M. R. Bell. 1977. Cotton leafperforator: Effect of a nuclear polyhedrosis virus on field populations. J. Econ. Entomol. 70: 727-8.

Young, S. Y., L. A. McCarel, and W. C. Yearian. 1980. Effect of *Bacillus thuringiensis*-*Trichoplusia ni* nuclear polyhedrosis virus mixtures on the cabbage looper, *Trichoplusia ni*. J. Ga. Entomol. Soc. 15: 1-8.