ATTRITION OF BEET ARMYWORM PUPAE IN INSECTICIDE-TREATED AND UNTREATED COTTON

John R. Ruberson, Stanley K. Diffie,
Gary A. Herzog, and Max H. Bass
Department of Entomology,
Coastal Plain Exp. Station,
Univ. of Georgia

Abstract

The rates of loss for beet armyworm pupae were examined in three different cotton fields: (1) treated with pyrethroid insecticide as needed for heliothine control, (2) untreated throughout the season, and (3) Bt-transgenic cotton that received no insecticide applications. Studies were conducted in 1994 and 1995, with 100 pupae placed in each field for each trial (2 trials in 1994 and 1 in 1995). Rates of pupal loss were highest in the untreated and Bt-transgenic cotton fields and were lowest in the pyrethroid-treated field in all trials, although the difference was not so great in 1995. The agents causing this loss were not apparent in the study, although fire ants were observed to remove pupae from their shallow cells in the ground. Fire ant activity was found to be reduced considerably by insecticide application -- repeated applications essentially eliminated fire ant activity. Other factors besides fire ants are apparently involved, as the reduction in fire ants did not correlate well with any increase in pupal survival.

Introduction

The beet armyworm, Spodoptera exigua, is an explosive, sporadic pest of cotton in portions of the southern U.S. However, its egg and larval stages are attacked by a large and effective complex of natural enemies that is capable of destroying a large percentage of the beet armyworm population (Ruberson et al. 1994). This complex can be disrupted by the use of various "hard" insecticides (e.g., organophosphates; Eveleens et al. 1973), releasing the beet armyworm population from the normal levels of natural suppression and permitting an outbreak to occur.

Although some data are available on natural enemies of the beet armyworm's egg and larval stages, and the rates of mortality inflicted on these life stages (Ruberson et al. 1994), comparable data are missing for the pupal stage. Beet armyworms pupate in the ground or in clods on the surface, usually directly beneath the plant canopy in the rows, where they remain until the adult moth emerges from the pupal case 6 to 14 days later (depending on temperature; Bass et al. 1978, Fye 1978, Pearson 1982). The pupal cell beneath the ground or in the clod is sealed at the surface by a "cap" of dirt, which is removed by the adult moth at the time of emergence. During the pupal period, the insects are exposed to a variety of climatic conditions (rain, high temperatures, etc.), as well as tillage and natural enemies. The purpose of the work reported here was to determine rates of beet armyworm pupal loss attributable to the activity of natural enemies and to evaluate the effect of a conventional insecticide program for budworm (Heliothis virescens) and bollworm (Helicoverpa zea) management on these rates of pupal loss. Although indirect efforts were also made to determine which species might be the most important natural enemies (through pitfall trapping), these efforts were secondary to the quantification of pupal loss.

Materials and Methods

The studies were conducted in 1994 and 1995 in three adjacent 5-acre cotton fields near Tifton GA. Two fields were planted with DPL 5415 cotton, and the third was planted with Bt-transformed 5415 (NuCotton). One field of non-transformed 5415 was left untreated with insecticide for the duration of the season, whereas the other received insecticides on an as-needed basis. In 1994 this latter field received 7 applications of the pyrethroid cyhalothrin (Karate 1EC), at 0.03 lbs AI/A; the dates of application relevant to this test were 12 July, 19 July, 26 July, and 2 August. In 1995 the conventionally-treated field received applications of the same material, at a rate of 0.028 lbs AI/A, on 13, 20, and 27 July, as well as 3, 10, and 18 August.

The method described by Kring et al. (1993) was employed to expose beet armyworm pupae to biotic mortality factors in the fields. Cans, open at both ends, were buried in the soil, with the upper lip of the can flush with the surrounding soil surface. The cans were placed in the fields in groups of 4, in a diamond shape with the 2 cans in the same row separated by 2 m, and a can flanked 1 m on each side (in the adjacent rows) of the center point between the two in-row cans. Twenty-five such groups (5x5 pattern; separated from one another by 20 m) were placed in each field on each of the experiment dates. One last-instar beet armyworm larva was placed on the soil surface bordered by the can's rim, beneath an inverted plastic cup that fit tightly inside the can rim. A diet cup was left on the soil surface with the larva to allow the larva to complete feeding prior to pupation. All larvae were checked the next day for pupation; pupation was verified by the presence of the dirt "cap" over the pupal cell. Any larvae dead or missing at this time were discarded from the experiment. Cups were removed from all individuals that had pupated so that they could be exposed to biotic and abiotic mortality factors during the course of the experiment. Tests of 100 larvae per field were placed in the field on 2 days in 1994 (12 July and 26 July) and on 1 day in 1995 (10 August).

Five days after cups were removed, 50% of the pupae were excavated to determine their fate. Depth of the pupal cells

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(to the top of the cell) was measured for each excavated pupa. Pupae were categorized as dead, missing, predated (body mutilated), or alive and intact. The remainder of the pupae were excavated when 50% of the adults had emerged from a protected group of 20 sentinel pupae in the untreated cotton field. This date occurred on the 10th day after pupation in both trials in 1994, and on day 9 for the test in 1995. For the final excavation (Day 9 or 10), pupae were characterized as above with the added category of successfully emerged adult. All pupae recovered alive from sample excavations were returned to the laboratory, where they were held to evaluate pupal parasitism.

Two methods were used to survey the fauna of soil-dwelling arthropod predators. The first involved the use of tuna in test tubes to trap foraging ants. Baited tubes (25 per field) were placed in the fields, in rows adjacent to the pupal sample groups, at approximately 0900 EST and recovered 45 min later on all sample dates. All ants in the tube were counted, and the number of ants in each tube was rated using a graded system. This method allowed us to quantify the relative activity of ants in the two fields. Ant activity was monitored in this manner on 2 dates during the course of each of the two trials in 1994: 11 July and 18 July (Trial 1), and 1 August and 8 August (Trial 2). The second trapping method involved use of pitfall traps. Twelve traps, consisting of 16 oz plastic cups, half filled with water and rock salt and buried to the lip in the ground, were placed in each field between the locations of the groups of cans. In 1994, pitfall traps were placed in the field on 12 July and were emptied weekly until 8 August. In 1995, pitfall traps were placed in the field on 8 August and emptied weekly until 22 August. Most specimens were identified to family, although some were identified to species. The data from these traps have not been entirely analyzed at this date, and are, therefore, not included in this presentation.

Results and Discussion

Successful pupation rates were high, exceeding 90% in all trials. Pupal cells were shallowly located relative to those of other noctuid species (Table 1), ranging from depths of 0.2 to 1.4 cm to the uppermost section of the cell chamber. Missing and predated pupae were both considered to have suffered mortal attrition, and are, therefore, pooled together in discussion of loss hereafter.

Rates of beet armyworm pupal loss differed among the 3 fields on all sample dates in both years (Table 2). In most cases pupal loss was 2-3 times greater in the untreated and Bt cotton than in the treated cotton, although this difference was not as pronounced in 1995 due to high loss in both treatments. These data suggest that at least some of the agents causing loss of beet armyworm pupae are being impaired by the applications of insecticides. The agents responsible for this loss, however, are difficult to ascertain. The ant trapping yielded only fire ants, Solenopsis invicta, in both years and in all fields. These ants were also observed removing parts of beet armyworm pupae from the sample sites, and are thus considered to be predators of beet armyworm pupae. Trapping revealed that fire ant activity was indeed greater in the untreated and Bt cotton relative to the pyrethroid-treated cotton (Table 3), and that ant activity in the insecticide-treated field declined with increasing number of insecticide applications in 1994. In 1995 the fire ants rebounded fairly rapidly, and had reached relatively high levels by 16 August. This may have accounted for the increased loss of beet armyworm pupae noted in 1995 relative to 1994. For 1994, however, the differences in fire ant activity among the fields were not reflected in the differences in beet armyworm pupal mortality - rates of loss within the 3 fields were comparable among sample dates and between trials, although fire ant activity steadily declined in the treated fields with increasing insecticide applications (Table 3). This suggests that additional mortality factors are at work.

No parasitoids were reared from any of the pupae excavated intact. All pupae but two yielded adult moths. The two pupae that failed to produce moths appeared to have been damaged during excavation.

Beet armyworms pupate relatively shallow in the soil (most less than 10 mm deep), compared with other noctuid species, such as the cotton bollworm Helicoverpa zea (see Kring et al. 1993) which often digs deeper than 50 mm. Shallow pupation may expose beet armyworm pupae to a higher risk of predation than other lepidopteran species that dig deeper. Thus, beet armyworm pupae suffer relatively high rates of loss - >25% in treated cotton, and considerably more in untreated fields - whereas the cotton bollworm suffers pupal mortality of less than 12% in corn (Kring et al. 1993).

Our results demonstrate that the differences in loss between the treated and untreated fields were due, at least in large part, to biotic factors (e.g., predators). If weather conditions had been responsible for the loss, rates of loss would have been comparable for all fields, whereas loss was consistently lower where the insecticide was used. In addition, more pupal remains would have been present in the pupal cells at the time of excavation. The causes of this loss remain unclear, however. Fire ants are certainly predators of the pupae, but other invertebrate predators are also likely involved. There was also some indication that vertebrate predation contributed to the loss of a few pupae - several pupae had considerable digging around the site. Such cases were, however, rare.

In conclusion, pupae of the beet armyworm suffer relatively high rates of loss in cotton, but this loss can be decreased substantially by use of pyrethroid insecticides. Appropriate management of fields to ensure high rates of loss for beet armyworm eggs and larvae, however, can likely offset the increased survival resulting from use of insecticides during the pupal stage. Use of Bt-transgenic cotton, with accompanying reductions in insecticide use, can contribute to the loss of beet armyworm pupae.

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Table 1. Depths of the uppermost region of beet armyworm pupal cells in test fields in 1994 and 1995 (Tifton GA).

	Pupal depth (mm)		
Trial date	Treated	Untreated	Bt
1994: Trial 1	7.0 + 3.31	4.4 + 3.09	5.9 + 3.59
1994: Trial 2	6.3 + 3.47	6.2 + 2.87	6.4 + 3.90
1995	5.3 + 7.23	4.2 + 2.20	5.1 + 3.00

Table 2. Percent survival of beet armyworm pupae in untreated cotton and cotton that received multiple applications of pyrethroid insecticide, and Bt-transgenic cotton.

	% survival		
Time of sample[1]	Treated	Untreated	Bt
1994: Trial 1 (12-25 July)			
5 d	73.9	21.7	38.8
n	46	46	49
10 d	58.7	31.3	40.8
n	46	48	49
1994: Trial 2 (26 July-8 August)			
5 d	68.0	35.4	28.6
n	50	48	48
10 d	61.2	26.0	33.3
n	49	50	48
1995 (10-21 August)			
5 d	42.0	0.0	6.3
n	50	50	48
10 d	26.0	12.0	4.0
n	50	50	50

[1]No. of days after pupation when pupation sites were excavated.

Table 3. Fire ant activity in the two fields on various sample dates. Insecticide was applied to the treated field on 12 July, 19 July, 26 July, and 2 August.

	Percent infestation/rating[1]		
Sample date	Treated	Untreated	Bt
1994			
11 July	32% / 0.64	36% / 1.04	24% / 0.36
18 July	28% / 0.48	72% / 1.36	60% / 0.92
1 August	4% / 0.08	56% / 1.20	48% / 0.96
8 August	0% / 0.00	68% / 1.44	76% / 1.64
1995			
3 August	12% / 0.48	96% / 4.76	100%/ 4.52
9 August	0% / 0.00	100%/ 4.29	100%/ 3.81
16 August	59% / 2.04	96% / 4.44	93% / 4.12

[1]Percent infestation refers to the percentage of traps in which fire ants were recovered. The rating refers to the relative abundance of ants within the traps. The rating scale was 0-5, with 5 being the highest number of ants.