DEFINING THE PERIOD OF BOLL SUSCEPTIBILITYTO FALL ARMYWORM INJURY IN COTTON

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Abstract

Fall armyworm 5th instars were caged on both conventional (DPL 5415) and transgenic Bt (NuCOTN 33) cotton bolls of various ages to define the period of boll susceptibility to larval injury. Larvae successfully caused injury throughout boll maturity on both varieties of cotton, suggesting that a period of boll tolerance to fall armyworm injury may not exist.

Introduction

The fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) (J. E. Smith) is a destructive pest throughout North America because of its efficient reproductive system, short developmental time, and ability to move in a highly variable pattern. This migratory moth overwinters in southern Florida and in a zone extending from South and Central America through southern Texas, from which it then migrates northward each spring and summer (Sparks 1979). Unlike most insects in the temperate regions, the fall armyworm has no diapause mechanism (Sparks 1979). It easily exploits agroecosystems, such as peanut, soybean, corn, and cotton in the southeastern United States.

The fall armyworm is a sporadic yet damaging pest on cotton, *Gossypium hirsutum* (L.). In the southeastern and mid-south states, the fall armyworm is an annual economic pest each season in Georgia, Alabama, Florida, and Louisiana (Smith 1985). In 1977, the pest caused significant damage to cotton throughout the southeastern United States (Bass 1978), and in 1984, caused economic damage in the Winter Garden area of Texas. In 1985, it was the single most damaging pest of cotton reported in Mississippi (King et al. 1986).

The distribution of early fall armyworm instars and method of insecticide application on cotton makes it a difficult pest to control. The majority of first and second fall armyworm instars appears to feed on cotton leaves located near the main stem (i.e. leaves from the most common oviposition sites) nodes 1 and 2 of the branches in the lower two-thirds of the plant (Ali et al. 1989, 1990). This is in sharp contrast with *Heliothis* species in which early instars are found on terminal buds on the cotton plant (Ramalho et al. 1984). Third instars move further away from the main stem and/or higher on the main stem than earlier instars. Later instars are located on middle to terminal portions of the plant including branch tips and appear to feed almost exclusively on fruiting structures (Ali et al. 1990). Current insecticide application procedures generally results in poor deposition on structures low in the canopy (Ali et al. 1990). Fall armyworm becomes more tolerant to insecticides as it increases in size (Yu 1983, Mink and Luttrell 1989). Thus, failure to control the early instars of fall armyworm leads to using higher concentrations of insecticides in attempts to control later stages of development. Furthermore, some evidence suggests that insecticides such as fenvalerate, permethrin, carbaryl, and methyl parathion, which are commonly used to control *Heliothis* spp., give little control of fall armyworm on cotton (Smith 1985).

Although numerous foliar insecticides are continuously being developed for fall armyworm control on cotton, inadequate deposition in the lower canopy of the plant where the majority of larvae are present suggests that control will continue to be limited. With the advent of transgenic *Bacillus thuringiensis* (Berliner) (Bt) technology, fall armyworm may be controlled with this technology because the ∆-endotoxin is expressed in bolls throughout the cotton plant including the lower canopy.

Studies with individual larvae (3-5th instars) caged on various stages of conventional cotton fruiting structures indicate that feeding of 4th and 5th instars on small bolls results in significant reductions in probability of harvest (Ali et al. 1990). However, the stage of development in which both conventional and transgenic Bt cotton bolls may be safe from fall armyworm injury is not known. Bagwell (1994) showed that after accumulating 350 heat units (HU), the conventional (non-Bt) boll reaches a point of resistance to 3rd instar bollworm, *Helicoverpa zea* (Boddie), damage. Thus, boll tolerance data combined with other management programs can be used to define insecticide termination for bollworm. Because some noctuid pests can cause more damage to bolls than others, boll tolerance data must be obtained for each noctuid pest that damage bolls to establish either individual or combined recommendations for insecticide termination for both conventional and transgenic Bt cotton. By defining the period of boll susceptibility to fall armyworm injury on both conventional and transgenic Bt cotton, we attempted to determine if differences existed between conventional and transgenic Bt cotton as well as obtain boll tolerance data for future insecticide termination recommendations.

Methods and Materials

Research was conducted at the Northeast Research Station, Macon Ridge Location, near Winnsboro, LA. Prior to infesting fall armyworms, white flowers on the cotton plants were tagged to record a boll's age in heat units (HU) as described in Bagwell (1994) as:

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Maximum daily temperature + Minimum daily temperature

__ (-) 60

2

Fall armyworms were collected from corn in southern Texas and Louisiana and reared for two to three generations on artificial diet prior to infestation. A fifth instar was placed into a cloth mesh bag with drawstrings and placed over a conventional cotton boll (DPL 5415) or a transgenic Bt cotton boll (NuCOTN 33) of various ages and closed tightly to minimize escape. After 72 hours, the bags were removed and percent of alive/dead larvae, escapes, and attempted/successful boll penetrations were recorded. Attempted penetration was defined as evidence of feeding on the external boll wall. Successful penetration was defined as the ability to penetrate through the boll wall to the seed/fiber (White 1995). A minimum of 18 larvae per heat-unit were used in both treatments.

Results and Discussion

Observations for larvae caged on DPL 5415 cotton are summarized in Table 1. Average number of larvae/heat unit was 24.3 with a total sample size of 267 larvae for 11 different heat units (39.5-852.0 HU). Larval survival ranged from 45.5 to 80.0%, while larval mortality was only 0.0 to 4.5%. Larval escapes were higher than deaths and ranged from 16.0 to 52.0%. Attempts at penetration were quite high throughout boll maturity and ranged from 72.7 to 100.0%. The percent of larvae successfully penetrating DPL 5414 bolls is shown in Figure 1. A curve fitting the data was selected based on the scatterplot and the highest r^2 value obtained; however, more data and/or analysis is needed before a more accurate line or curve can be drawn. Larvae were at least 50% successful in penetrating bolls throughout boll maturity.

Observations for larvae caged on NuCOTN 33 cotton are summarized in Table 2. Average number of larvae/heat unit was 30.0 with a total sample size of 740 larvae for 20 different heat units (20.5-726.5 HU). Larval survival ranged from 32.7 to 90.5%, while larval mortality was only 0.0 to 14.8%. Larval escapes were higher than deaths and ranged from 9.5 to 65.3%. Attempts at penetration were quite high throughout boll maturity and ranged from 63.3 to 100.0%. The percent of larvae successfully penetrating NuCOTN 33 bolls is shown in Figure 2. A curve fitting the data was selected based on the scatterplot and the highest r^2 value obtained; however, more data and/or analysis is needed before a more accurate line or curve can be drawn. Larvae were at least 49% successful in penetrating bolls from 20.5 to 375.5 HU. Larval success at penetrating bolls declined sharply between 375.5 and 499.0 HU eventually reaching 0% at 519.0 HU. However, larval success at penetration increased to 42.9% at 558.5 HU and 33.3% at 726.5 HU. Throughout boll development, fall armyworm larvae successfully penetrated bolls in both treatments. Cotton plants are considered safe to defoliate when bolls have accumulated at least 750 HU and are opening at $\geq$ 850 HU. At least 60% of the DPL 5415 bolls were penetrated after plants were safe to defoliate and ready to open. On DPL 5415, bolls were not safe from 5th instar fall armyworm injury at any period during this test. In the NuCOTN 33 treatment, two data points near 500 HU indicate low penetration success (0.0 and 11.0%). However, the ability of larvae to penetrate bolls between 550-725 HU (>30.0%) suggests that the small number of larvae successfully penetrating bolls of approximately 500 HU may be explained by extremely high temperatures recorded during this time period, which adversely affected fall armyworm feeding, although attempts at penetration are still quite high (73.1-77.8%). Another explanation could be that the Δ-endotoxin found in NuCOTN 33 is not expressed at high enough levels late in boll maturity (>550 HU) to deter fall armyworm feeding. However, more data is needed to distinguish between these two hypotheses. Although NuCOTN 33 may provide some boll protection against fall armyworm, the ability of larvae to penetrate bolls near boll maturity and opening indicates that 5th instars can cause injury throughout boll development.

Unlike the bollworm, where after 350 HU the conventional boll reaches its point of maximum resistance (Bagwell 1994), no definable period of boll tolerance for conventional and transgenic Bt cotton was determined for fall armyworm. Our data indicates that boll tolerance differs among noctuid pests and should be determined for each pest before using such data for insecticide termination.

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Table 1. Observations recorded for larvae caged on DPL 5415.

N	Heat Units	%Alive	%Dead	%Escape	%Attempt Penetration
25	39.5	64.0	0.0	36.0	84.0
25	112.0	45.5	4.5	50.0	72.7
25	133.5	68.0	4.0	28.0	96.0
24	249.5	62.5	0.0	37.5	91.7
24	251.0	70.8	4.2	25.0	100.0
25	272.5	48.0	0.0	52.0	76.0
24	383.0	54.2	4.2	41.6	100.0
25	500.5	80.0	4.0	16.0	100.0
23	522.0	60.9	0.0	39.1	82.6
25	585.5	80.0	0.0	20.0	88.0
25	852.0	48.0	4.0	48.0	80.0

Table 2. Observations recorded for larvae caged on NuCOTN 33.

N	Heat Units	%Alive	%Dead	%Escape	%Attempt Penetration
49	20.5	32.7	2.0	65.3	63.3
28	45.5	0.7	3.6	35.7	75.0
48	82.5	75.0	0.0	25.0	89.6
48	104.5	62.5	0.0	37.5	77.1
48	124.5	60.4	2.1	37.5	93.8
48	141.5	70.8	0.0	29.2	89.6
39	197.5	69.2	2.6	28.2	76.9
45	219.5	51.1	2.2	46.7	71.1
48	239.5	75.0	2.1	22.9	87.5
47	251.0	66.0	4.2	29.8	91.5
28	302.0	60.7	0.0	39.3	85.7
49	355.5	38.8	4.1	57.1	89.8
49	375.5	63.3	6.1	30.6	95.9
25	439.0	40.0	0.0	60.0	100.0
25	459.0	60.0	0.0	40.0	96.0
18	499.0	50.0	5.6	44.4	77.8
26	519.0	53.9	3.8	42.3	73.1
21	558.5	90.5	0.0	9.5	90.5
24	642.5	70.8	4.2	25.0	91.7
27	726.5	51.9	14.8	33.3	70.4

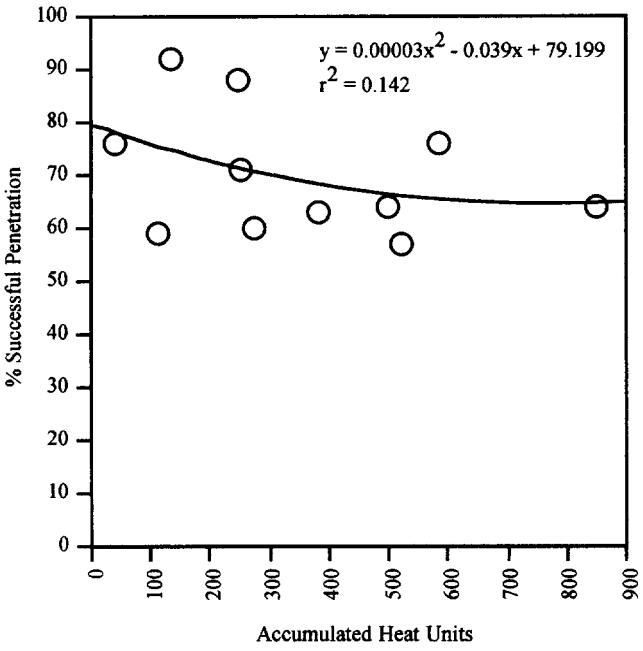

Figure 1. % Successful penetration vs accumulated heat units for larvae caged on DPL 5415.

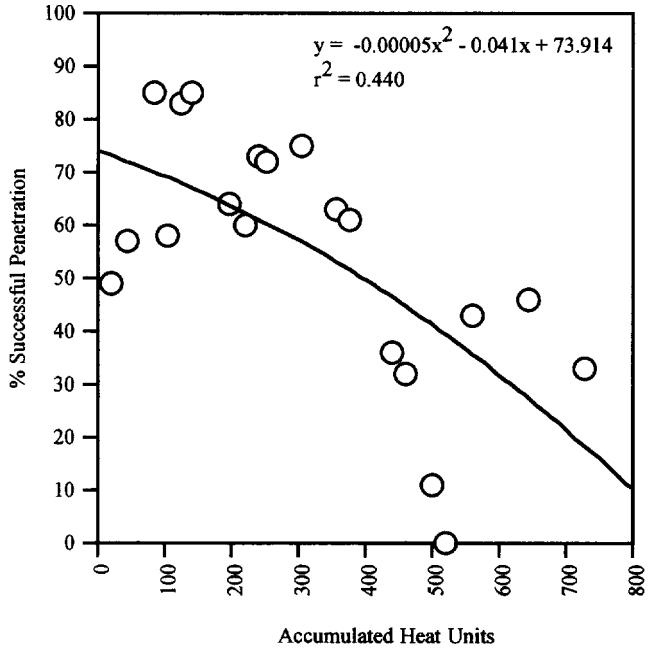

Figure 2. % successful penetration vs accumulated heat units for larvae caged on NuCOTN 33.