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DEFINING BOLL AND YIELD TOLERANCE TO LATE-SEASON COTTON INSECT PESTS IN LOUISIANA

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Abstract

Field tests were conducted in northeastern Louisiana from 1995-2003 to define boll and yield tolerance to late-season cotton pests. The insect pests included bollworm, fall armyworm, beet armyworm, tarnished plant bug and brown stink bug. Lepidopteran larvae and "bugs" were caged on cotton bolls of various ages to define the period of boll susceptibility to insect injury. Bolls that accumulated 426.5 (17.1 d) HU beyond anthesis before infestation were not injured by first-instar bollworm larvae. Bolls accumulating 350 HU were successfully penetrated by fall armyworm and beet armyworm at unacceptable (≥ 10%) levels. For tarnished plant bugs, seedcotton yields were significantly lower for bolls that had accumulated between 99 to 326.5 HU after anthesis, compared to non-infested bolls. Seedcotton yields were significantly lower for brown stink bug infested bolls compared to that of non-infested bolls through ca. 550 HU beyond anthesis. Insect-simulated defoliation of cotton at 66% and 99% leaf removal resulted in mean seedcotton yield losses of 23.8% and 51.1%, respectively, below that in the non-defoliated plots at 350 HU after anthesis.

Introduction

Cotton insect pest management in the United States relies heavily on insecticide-based crop protection strategies. Research efforts to improve cotton insect pest control with insecticides have generally focused on application timing of the initial treatments when pests have exceeded economic thresholds. One of the most important facts used in the decision to terminate insecticide treatments during the late season is crop status (Bernhardt and Phillips 1982). A cotton crop reaches its maximum economic value at the end of the production season, and plant maturity becomes an important factor in tolerance of the harvestable yield to insect pest injury. Late-season insect pest management decisions consider several factors, including the relationship between boll maturity and susceptibility to insect pest injury.

Investigators have determined the period of boll susceptibility to selected insect pests, including adult boll weevils, *Anthonomus grandis grandis* Boheman; bollworm, *Helicoverpa zea* (Boddie), larvae; beet armyworm, *Spodoptera exigua* (Hübner), larvae; tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), adults; and fall armyworm, *Spodoptera frugiperda* (J. E. Smith), larvae (Bagwell and Tugwell 1992, Adamczyk et al. 1998, Russell 1999). The developmental rate of a cotton boll is closely associated with temperature; therefore, boll development is based on heat unit (HU) accumulation rather than age (Bagwell and Tugwell 1992).

The objective of this report is to review selected reports that demonstrate boll/yield tolerance to late-season insect pests in Louisiana.

Materials and Methods

Field studies were conducted at the Macon Ridge Research Station (LSU AgCenter) near Winnsboro, Louisiana from 1995-2003. The insect pests included bollworm, fall armyworm, beet armyworm, tarnished plant bug and brown stink bug, *Euschistus servus* (Say). Plots consisted of 3-16 rows depending on the specific insect. Treatments (infested and non-infested) were arranged in a randomized complete block design.

Cotton plant development was monitored twice per week by recording the rate of white flower production. First-position white flowers (flowers located on the first fruiting node of a sympodial branch) were tagged daily. Yellow "snap-on" tags, labeled with the date of anthesis, were attached to a sympodial branch between the main stem and the flower pedicel. Cotton bolls were classed according to HU accumulation methods from the date of anthesis to the date of infestation as described by Bagwell and Tugwell (1992). HU were calculated as: heat unit = ([maximum daily temperature + minimum daily temperature]/2) – 60, where 60°F is the minimum temperature for normal cotton plant development (Landivar and Benedict 1996). Incidence of feeding was defined as evidence of the ability of a larva to completely penetrate the boll walls (i.e., exocarp and endocarp into the seed or fiber (White 1995).

Lepidopteran Pests

All species (bollworm, fall armyworm and beet armyworm) were reared for a minimum of two generations in the laboratory to eliminate diseases and parasitoids before infesting cotton bolls. Larvae were reared according to the methods described on Perkins (1979) by using a soybean and wheat germ meridic diet (King and Hartley 1985). Pupae of each species were placed into individual cardboard cylinders (3.79 liter) lined with wax paper and covered with cheesecloth. Moths were fed a 10% sugar water solution. Eggs were harvested daily from sheets of cheesecloth and wax paper, and maintained in an environmental chamber at 27± 1°C and a photoperiod of 14:10 (L:D) h. Neonate larvae were transferred to 29.6-ml cups containing artificial diet, capped, and reared as previously described. A nylon mesh (no. 280) exclusion cage (15 by 11.5 cm), with drawstrings, was placed over each fruiting form and closed tightly around the pedicel to exclude natural enemies. The date of infestation was recorded on the snap-on tags for each individual boll. Controls consisted of caged, non-infested fruiting forms within the same age classes as infested bolls.

Approximately 24 ± 3 h after eclosion, first-instar bollworm larvae (one larva per fruiting form) were placed on individual white flowers or various-aged bolls of using a fine camel's hair brush. Ten to 100 larvae were infested within each age class on fruiting forms ranging from 0 (white flower) to 478 (19.1 d) HU.

Fifth-instars (300-400 mg) were used for fall armyworm infestations and third-instars (30-45 mg) were used for beet armyworm infestations. Beet armyworms tend to feed on bracts of fruiting forms (Smith 1985) and the bracts were removed before infestation to ensure that larvae fed only on bolls. A single larva was placed into a mesh bag and placed on bolls of various HU.

Bags and larvae were removed 72 h after infestation. Percentage boll abscission was recorded at 72 h after infestation, 7 d after infestation, and at harvest. Abscission data for infested bolls were corrected for natural abscission in the non-infested bolls using Abbott's formula (Abbott 1925). Corrected abscission (dependent variable) data were plotted against accumulated HU (independent variable) of infested fruiting forms to develop regression equations describing this relationship (SAS Institute 1998). Only those HU in which abscission actually occurred were included in the model. Bolls were individually harvested and seedcotton weights were recorded at the end of the season. Yield data were analyzed using Bonferroni's *t*-tests comparing weights of infested bolls with those of non-infested bolls within the same HU class (SAS Institute 1998). Regression analysis (PROC REG, SAS Institute 1998) was used to determine if there was a significant relationship between boll penetration and accumulated HU (boll age). In all regression analyses, linear relationships were used for all regression models, because higher order polynomials did not improve the fit of the model.

Hemipteran Pests

Tarnished plant bugs were collected from cotton and native hosts in northeast Louisiana using a standard 38.1 cm diameter sweep net. Insects were held in a 0.457 m^3 wire mesh cage in the laboratory for 24 h to reduce mortality from physical injury and disease. Tarnished plant bugs were fed washed green beans, *Phaseolus vulgaris* (L.), and 10% sugar water to maintain the health of the insects in the laboratory. The insects were placed into 20 ml glass vials and transported to the field in a chilled ice cooler to eliminate tarnished plant bug mortality from heat stress. Two tarnished plant bug adults were placed into the mesh bags and then caged on an individual boll for 72 h. Multiple first position bolls were used on individual plants; however, bolls were selected at similar fruiting positions on adjacent plants to compare the control treatments to the infested bolls. Tarnished plant bug infestations began at white flower (0 HU) and continued until bolls had accumulated 487 HU beyond anthesis.

Brown stink bug adults were collected during May and Jun of 2001 and 2002 from mustard, *Brassica* spp., and corn, *Zea mays* L. Insects were collected and maintained in a manner similar to that for tarnished plant bugs. One brown stink bug adult per nylon mesh cage was placed on an individual boll. Stink bugs were caged on each boll for 72 h, at which time the cages and insects were removed. Stink bug infestations were initiated at white flower (0 HU) and continued through 892 HU beyond anthesis.

All harvestable bolls were individually collected and seedcotton weights were recorded. The number of abscised bolls was recorded at the time of harvest. For tarnished plant bugs, HU were pooled in increments of the daily HU mean (25 HU) in order to perform analyses on boll weight. For brown stink bugs, cumulative abscission data and weights of individual bolls within the same HU were then grouped into 17 classes of 50 HU, ranging from 0-50 to 851-900. Data analysis was similar to lepidopteran pests. Boll abscission data for infested bolls was corrected for natural abscission in the non-infested bolls and analyzed using regression analysis.

Insect Simulated Defoliation

Node above white flower (NAWF) and HU accumulations were used to characterize the late-season reproductive stages of plant maturity. Plant heights were used to divide plants into three similar vertical zones (bottom, middle, and top) at the NAWF5 + 350 HU growth stage. Insect simulated defoliation levels of 33%, 66%, and 99% corresponded to complete leaf removal in the bottom zone, bottom + middle zones, and bottom + middle + top zones, respectively. Seedcotton yields were determined by hand-harvesting both rows.

At the time of cutout (NAWF = 5), a yellow "snap-on-tag" was placed on the internode above the fifth main stem node below the terminal on each plant in the plot to differentiate between bolls set before and after cutout. HU accumulated beyond cutout were monitored. As the respective number of HU were accumulated (450, 550, 650, 750 and 850) plots were defoliated. Defoliation was accomplished by removing the bottom 66% of the plant foliage with scissors. Two weeks after each treatment was applied, all seedcotton from the center row of the three row plot was hand harvested. Yield data were analyzed with ANOVA and treatment means were separated according to DMRT ($\underline{P}$=0.05).

Results

Bollworm

Bolls that accumulated 253 (10.1 d) HU beyond anthesis were safe from bollworm-induced abscission at the time of harvest. Bollworm larvae reduced seedcotton weights of bolls that accumulated between 58.5 (2.3 d) and 350.5 (14.0 d) HU beyond anthesis. Bolls that accumulated 426.5 (17.1 d) HU beyond anthesis were not injured by first-instar bollworm larvae.

Fall Armyworm and Beet Armyworm

Fall armyworms penetrated ≥ 60% of non-transgenic bolls regardless of their age; however, bolls were tolerant (≤ 10% boll penetration) to beet armyworms at 390 HU. Bolls were tolerant to fall armyworm damage at 864 HU, but these bolls were tolerant to beet armyworm damage at 361 HU. These data suggest that fall armyworms and beet armyworms are able to successfully penetrate bolls of 350 HU at unacceptable (≥ 10%) levels. For both species that were caged, there was a significant linear relationship between boll penetration and boll age that was observed with boll penetration decreasing as the bolls matured.

Tarnished Plant Bug

Boll abscission rates declined to 0% at 245 HU beyond anthesis. Seedcotton yields were significantly lower for bolls that had accumulated between 99 to 326.5 HU after anthesis, compared to non-infested bolls.

Brown Stink Bug

Brown stink bugs induced boll abscission through ca. 350 HU beyond anthesis. Boll abscission ranged from 50.9% for bolls infested at 51-100 HU to 0% for bolls infested at ≥ 351 HU (14.0 d) beyond the date of anthesis. Seedcotton yield was significantly lower for infested bolls as compared to non-infested bolls through ca. 550 HU beyond anthesis. No yield loss occurred when a boll accumulated ≥ 550 HU beyond anthesis (ca. 22 d beyond anthesis).

Insect Simulated Defoliation

As defoliation levels increased from 0 to 99% at the NAWF5 + 350 HU stage of development, yields consistently declined. Significant yield losses were observed at defoliation levels > 33%. Defoliation of 66% and 99% resulted in mean seedcotton yield losses 23.8% and 51.1%, respectively, below that in the non-defoliated plots. Removal of the cotton foliage (66%) as early as 450 HU beyond cutout did not negatively impact total seedcotton yield in 2003. This is attributed to droughty conditions late-season resulting in minimal boll set after cutout and negligible contribution of the 'top crop' to overall yield.

Summary

These data provide substantial information about late-season insecticide termination strategies for selected cotton insect pests on cotton. This will help pest managers determine when insecticides are no longer economical during the late-season. Boll tolerance differs among all pests; therefore, boll susceptibility at various developmental stages should be determined for each pest to refine late-season insect pest management termination strategies. Using the information on crop development, boll maturity, and knowledge concerning the relationship between boll age and insect pest injury, accurate timing for the termination of late-season crop protection strategies without a yield penalty should be easily accomplished.

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