COTTON BOLL SUSCEPTIBILITY TO FALL ARMYWORM AND BEET ARMYWORM INJURY

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Abstract

Fifth instar fall armyworms, *Spodoptera frugiperda* (J. E. Smith), and third instar beet armyworms, *Spodoptera exigua* (Hübner), were caged on conventional (cv. DP 5415) and transgenic *Bacillus thuringiensis* (Bt) cotton bolls (cv. NuCOTN 33[B)] of various ages to define the period of boll susceptibility to larval injury. Larval mortality, incidence of feeding, and boll penetration were examined for both cultivars. There was no significant linear relationship between incidence of feeding and boll age for either species caged on DP 5415 and NuCOTN 33[B]. However, a significant linear relationship between larval mortality and boll age was observed for both species caged on NuCOTN 33[B] (mortality increased as bolls matured), but no such relationship was found on DP 5415. A significant linear relationship between boll penetration and boll age was observed for both species caged on NuCOTN 33[B] (boll penetration decreased as bolls matured). Similarly, a significant linear relationship between boll penetration and boll age was observed for beet armyworms caged on DP 5415 (boll penetration decreased as bolls matured), while no relationship was found for fall armyworms caged on DP 5415. Fall armyworms penetrated ≥ 60% of DP 5415 bolls regardless of their age, while these bolls were tolerant (≤ 10% boll penetration) to beet armyworms at 390 heat units. NuCOTN 33[B] bolls were tolerant to fall armyworm damage at 864 heat units, while these bolls were tolerant to beet armyworm damage at 361 heat units. These data suggest that fall armyworms and beet armyworms are able to successfully penetrate bolls of 350 heat units at unacceptable (≥ 10%) levels.

Introduction

The fall armyworm, *Spodoptera frugiperda* (J. E. Smith), and the beet armyworm, *Spodoptera exigua* (Hübner), are considered sporadic, but significant pests of cotton, *Gossypium hirsutum* L., from North Carolina to Texas (Smith, 1985). Recently, outbreaks of beet armyworm populations contributed to the severe cotton yield losses reported in the Lower Rio Grande Valley of Texas in 1995 (Summy et al., 1996). In addition, local outbreaks of the fall armyworm were reported in 1996 to both conventional cotton and transgenic *Bacillus thuringiensis* (Bt) cotton in southern Alabama and Georgia (Hood, 1997; Smith, 1997).

The developmental rate of a cotton boll is closely associated with temperature. Boll development is classified based on heat unit accumulation rather than age (Bagwell and Tugwell, 1992). Management of cotton development often is determined by counting the nodes above the uppermost white flower in the first fruiting position of the cotton plant (nodes above white flower = NAWF) (Bernhardt et al., 1986) and combining that data with boll age (heat unit accumulation) (Bagwell and Tugwell, 1992; Torrey et al., 1997). Bagwell (1994) showed that after accumulating 350 heat units, conventional cotton bolls attain maximum resistance to third instar bollworm, *Helicoverpa zea* (Boddie). Those data suggested that insecticide control of this pest on cotton could be terminated when the last population of bolls contributing to yield have accumulated at least 350 heat units. While similar data has been obtained for the boll weevil, *Anthonomus grandis grandis* (Boheman) (Bagwell, 1994), other cotton pests, such as fall armyworms and beet armyworms, have not been fully examined. Therefore, boll tolerance data must be obtained for each pest that can damage bolls to establish recommendations for termination of insect control strategies in conventional and transgenic Bt cotton. This study was conducted to define the period of boll susceptibility to fall armyworm and beet armyworm injury on conventional as well as transgenic Bt cotton.

Materials and Methods

All experiments were conducted from June-August during 1995-1997. Transgenic Bt cotton (cv. NuCOTN 33[B]) containing the Bollgard™ gene (Monsanto Co., St. Louis, MO 63167) and its conventional cotton parental lines (cv. DP 5415) used in these experiments were grown at the Macon Ridge Location of the Northeast Research Station (Louisiana State University Agricultural Center, Louisiana Agricultural Experiment Station) near Winnsboro, LA. Field collections of beet armyworms were made from cotton near Evelyn, LA and Tift Co., GA in 1995 and 1996, respectively. Field collections of fall armyworm were made from field corn, *Zea mays* L., near Brownsville, TX and Baton Rouge, LA in 1996, and from the Macon Ridge Location of the Northeast Research Station in 1997.

Boll Infestations

Yellow "snap on tags" (A. M. Leonard, Inc., Piqua, OH) were labelled with the date of anthesis, and placed around the petioles of the corresponding first position white flowers on cotton plants. The daily growth of tagged bolls was recorded in heat units described in Bagwell and Tugwell (1992) as: (maximum + minimum daily temperature/2) - 60, where 60 is considered the minimum temperature at which development occurs. The age class of cotton bolls at infestation was calculated by accumulating heat units from the initial date of anthesis to time of infestation.

Fifth instars (300-400 mg) were utilized for fall armyworm infestations, while 3rd instars (30-45 mg) were utilized for

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beet armyworm infestations. Because beet armyworm tend to feed on bracts of fruiting forms (Smith, 1985), the bracts were removed before infestation to ensure that larvae fed only on bolls. A single larvae was placed into a 15 cm X 11.5 cm cloth mesh bag #280 with drawstrings and placed over DP 5415 or NuCOTN 33^B bolls in various stages (heat units) and closed tightly to minimize escape. After 72 hours, the bagged bolls were excised from the plant and larval mortality, incidence of feeding, and boll penetration, were recorded. Larval mortality was defined as no movement after 10 seconds of prodding with blunt forceps. Incidence of feeding was defined as evidence of larval feeding on the external boll wall. Boll penetration was defined as the ability of a larva to completely penetrate through the boll walls (i.e. exocarp and endocarp) into the seed/fiber (White, 1995).

In 1996, fall armyworms were infested on both DP 5415 and NuCOTN 33^B bolls, while only NuCOTN 33^B bolls were infested in 1997. For DP 5415, the mean number of fall armyworm larvae infested per heat unit was 24.3 with a total sample size of 267 larvae for 11 different heat units (39.5-852.0 heat units). Initial regression analysis (SAS Institute, 1985) for fall armyworm infested on NuCOTN 33^B bolls revealed no significant differences ($P > 0.05$) between the slopes and Y-intercepts for all observations collected during 1996 and 1997. Therefore, these data were combined to obtain a larger sample size. For NuCOTN 33^B, the mean number of fall armyworm larvae infested per heat unit was 33.5 with a total sample size of 1172 larvae for 35 different heat units (20.5-780.0 heat units).

In 1995, beet armyworms were infested on DP 5415 bolls, while NuCOTN 33^B bolls were infested in 1996. For DP 5415, the mean number of beet armyworm larvae infested per heat unit was 27.8 with a total sample size of 333 larvae for 12 different heat units (22.5-360.5 heat units). For NuCOTN 33^B, the mean number of beet armyworm larvae infested per heat unit was 26.1 with a total sample size of 469 larvae for 18 different heat units (17.0-460.5 heat units).

Data Analyses

For each species and cultivar, regression analysis (SAS Institute, 1985) was used to determine if there was a significant relationship between larval mortality, incidence of feeding, or boll penetration and accumulated heat units (boll age). In all regression analyses, linear relationships were used for all regression models, because higher polynomials did not improve the fit of the model.

Results

Fall Armyworm

Fall armyworms caged on DP 5415 penetrated $\geq$ 60% of bolls regardless of their age. Larval mortality was low, ranging from 0.0 to 4.5%. Incidence of feeding was high regardless of boll age, and ranged from 72.7 to 100.0%. There was no significant linear relationship ($P > 0.05$) describing larval mortality ($R^2 = 0.003$; $F = 0.026$; df = 1,9; $P = 0.876$), incidence of feeding ($R^2 = 0.001$; $F = 0.001$; df = 1,9; $P = 0.974$), or boll penetration ($R^2 = 0.145$; $F = 1.53$; df = 1,9; $P = 0.248$) as a function of accumulated heat units.

The regression equation indicated NuCOTN 33^B bolls were tolerant ($\leq$ 10% boll penetration) to fifth instar fall armyworm damage at 864 heat units. However at this age, cotton fiber would be mature and bolls are normally opening (Landivar and Benedict, 1996). In addition, $\geq$ 11% of larvae were able to penetrate mature NuCOTN 33^B bolls that were near opening (between 750 and 850 heat units). Larval mortality was low, ranging from 0.0 to 14.8%. Incidence of feeding was high regardless of boll age, and ranged from 57.1 to 100.0%. There was no significant linear relationship ($P > 0.05$) describing incidence of feeding ($R^2 = 0.019$; $F = 0.625$; df = 1,33; $P = 0.435$) as a function of accumulated heat units. However, there was a significant linear relationship ($P < 0.05$) describing larval mortality ($R^2 = 0.429$; $F = 24.8$; df = 1,33; $P \leq 0.0001$) as a function of accumulated heat units, indicating that larval mortality increased as NuCOTN 33^B bolls developed. In addition, there was a significant linear relationship ($P < 0.05$) describing boll penetration as a function of accumulated heat units ($R^2 = 0.634$; $F = 57.1$; df = 1,33; $P \leq 0.0001$), indicating that boll penetration decreased as NuCOTN 33^B bolls developed.

Beet Armyworm

The regression equation indicated DP 5415 bolls were tolerant ($\leq$ 10% boll penetration) to third instar beet armyworm damage at 390 heat units. Larval mortality ranged from 0.0 to 25.0%. Incidence of feeding was high regardless of boll age, and ranged from 73.3 to 100.0%. There was no significant linear relationship ($P > 0.05$) describing larval mortality ($R^2 = 0.223$; $F = 2.87$; df = 1,10; $P = 0.121$) or incidence of feeding ($R^2 = 0.029$; $F = 0.295$; df = 1,10; $P = 0.599$) as a function of accumulated heat units. However, there was a significant linear relationship ($P < 0.05$) describing boll penetration as a function of accumulated heat units ($R^2 = 0.523$; $F = 10.9$; df = 1,10; $P = 0.008$), indicating that boll penetration decreased as DP 5415 bolls developed.

The regression equation showed that NuCOTN 33^B bolls were tolerant ($\leq$ 10% boll penetration) to third instar beet armyworm damage at 361 heat units. Larval mortality was low, ranging from 0.0 to 25.0%. Incidence of feeding was again high regardless of boll age, and ranged from 46.4 to 100.0%. There was no significant linear relationship ($P > 0.05$) describing incidence of feeding ($R^2 = 0.003$; $F = 0.047$; df = 1,16; $P = 0.831$) as a function of accumulated heat units. However, there was a significant linear relationship ($P < 0.05$) describing larval mortality ($R^2 = 0.351$; $F = 8.65$; df = 1,16; $P = 0.010$) as a function of accumulated heat units, indicating that larval mortality increased as NuCOTN 33[B] bolls developed. There also was a significant linear relationship ($P < 0.05$) describing boll penetration ($R^2 = 0.880$; $F = 117$; df = 1,16; $P \leq 0.0001$) as a function of accumulated heat units, indicating that boll penetration decreased as NuCOTN 33[B] bolls developed.

Discussion

Fall armyworms and beet armyworms damaged bolls of 350 heat units at unacceptable levels, unlike other insects, such as bollworms and boll weevils, where after 350 heat units the conventional cotton boll reaches a point of maximum tolerance (Bagwell 1994). If insecticide applications are terminated when bolls have accumulated 350 heat units, without concerns for other pests such as fall armyworms and beet armyworms, yield losses may result. Thus, when using this insecticide termination rule for commonly occurring bollworms and boll weevils, frequently scouting cotton fields for other pests is necessary to determine if additional IPM strategies are needed.

Producers should exercise caution when using insecticide termination treatments. Further data are needed to determine boll tolerance levels for all larval stages of fall armyworms and beet armyworms, because all larval stages will feed on fruiting forms (Ali et al., 1990; Smith, 1985). This study also indicated boll tolerance differs among noctuid pests. Therefore, boll susceptibility at various developmental stages should be determined for each pest to refine termination of insect control strategies in cases where multiple pests occur.

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References

Ali, A., R. G. Luttrell and H. N. Pitre. 1990. Feeding sites and distribution of fall armyworm (Lepidoptera: Noctuidae) larvae on cotton. Environ. Entomol. 19: 1060-1067.

Bagwell, R. D. 1994. Monitoring the cotton plant for insecticide effects and late-season insecticide use termination. PhD dissertation, Univ. of Arkansas, Fayetteville, AR. 88 pp.

Bagwell, R. D. and N. P. Tugwell. 1992. Defining the period of boll susceptibility to insect damage in heat-units from flower. pp. 767-768. *In* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Bernhardt, J. L., J. R. Phillips and N. P. Tugwell. 1986. Position of the uppermost white bloom defined by node counts as an indicator for termination of insecticide treatments in cotton. J. Econ. Entomol. 79: 1430-1438.

Hood, E. 1997. The fall armyworm: and I thought I had it made. pp. 1223-1224. *In* Proc., Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Landivar, J. A. and J. H. Benedict. 1996. Monitoring system for the management of cotton growth and fruiting. Bulletin B-2. The Texas A&M University System, Texas Agricultural Experiment Station.

SAS Institute. 1985. Statistics, version 5 ed. SAS Institute. Cary, NC.

Smith, R. H. 1985. Fall and beet armyworm control. pp. 134-136. *In* Proc., Beltwide Cotton Prod. Res. Conf., National Cotton Council, Memphis, TN.

Smith, R. H. 1997. An extension entomologists' 1996 observations of Bollgard (Bt) technology. pp. 856-857. *In* Proc., Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Summy, K. R., J. R. Raulston, D. Spurgeon and J. Vargas. 1996. An analysis of the beet armyworm outbreaks on cotton in the lower Rio Grande Valley of Texas during the 1995 production season. pp. 837-843. *In* Proc., Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Torrey, K. D., J. H. Fife, B. R. Leonard, R. D. Bagwell, E. Burris, D. Cook, V. Mascarenhas and J. Adamczyk. 1997. Confirmation of insecticide termination rules in Louisiana. pp. 1335-1338. *In* Proc., Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

White, C. A. 1995. Management of bollworm, *Helicoverpa zea* (Boddie), and tobacco budworm, *Heliothis virescens* (F.), with transgenic *Bt* cotton genotypes, microbial insecticide, and conventional insect resistance traits in cotton. PhD dissertation. Louisiana State University, Baton Rouge, LA.