RESPONSES OF A BT COTTON CULTIVAR (DP NUCOTN 33B) TO SELECTED LEVELS OF BOLL INJURY

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Abstract

Plant maturity and yield responses of a transgenic *Bacillus thuringiensis* Berliner var. *kurstaki* (Bt) cotton cultivar (NuCOTN 33B) were measured after 7 levels (0, 2.5, 5, 10, 20, 40 and 80%) of mechanical boll injury were applied during each of the first 4 weeks of flowering during 1997 and 1998. Injury was produced by drilling a hole completely through bolls using a portable drill and bit (0.25 in. diameter) to simulate feeding by late instar Lepidopteran larvae. At the end of the season, crop maturity (percent open bolls) and seedcotton weights were recorded. No level of injury applied during the first 2 weeks of flowering significantly delayed crop maturity in 1997. Crop maturity was significantly delayed when boll injury was applied during weeks 3 and 4 of flowering in 1997. Percent open bolls ranged from 73-41% and 72-12% during weeks 3 and 4 of flowering, respectively, for 0-80% boll injury. Seedcotton weight was not significantly affected by boll injury when applied during the first 2 weeks of flowering in 1997. Boll injury applied during weeks 3 and 4 of flowering significantly reduced seedcotton yield by 5-16% and 0-32%, respectively, for 2.5-80% boll injury. Boll injury applied in 1998 produced results similar to those observed in 1997 for crop maturity. The only significant delays in crop maturity occurred during weeks 3 and 4 of flowering. Percent open bolls ranged from 81-47% and 87-26% during weeks 3 and 4 of flowering, respectively, for 0-80% boll injury. Seedcotton weight was not significantly affected by any level of boll injury applied during each of the first 4 weeks of flowering in 1998.

Introduction

Cotton, *Gossypium hirsutum* L., is an important agronomic crop in the United States with over 10.4 million acres being harvested in 1998. Cotton plants have an indeterminate growth pattern and produce vegetative (monopodial) and reproductive (sympodial) structures. The indeterminate growth habit allows cotton plants to produce more fruiting structures than can mature to harvest. Therefore, the cotton plant can compensate for the loss of fruiting structures by retaining structures at positions that would have abscised under normal conditions. Several investigators have shown that cotton plants can compensate for fruiting form loss during the pre-flowering period (Dunnam et al. 1943; Mistric and Covington 1968; Kennedy et al. 1986, 1991; Pettigrew et al. 1992; Jones et al. 1996).

The loss of fruiting structures can occur through natural abscission or as a result of injury. One key factor leading to the unnatural abscission of fruiting forms is injury from insect pests such as the boll weevil, *Anthonomus grandis grandis* Boheman, and Lepidopteran pests such as the bollworm, *Helicoverpa zea* (Boddie), tobacco budworm, *Heliothis virescens* (F.), or armyworms, *Spodoptera* spp.

Since the introduction of transgenic cotton cultivars containing the Bollgardä gene (Monsanto Co., St. Louis, MO), considerable concerns have arisen about proper insecticide application timing for non-target Lepidoteran pests. These cultivars are not entirely resistant to bollworm attack and economic damage may occur in the presence of persistent, high populations. In 1996 and 1997, bollworm infestations required supplemental foliar applications of insecticides in many transgenic *Bacillus thuringiensis* Berliner var. *kurstaki* (Bt) cotton fields throughout the Southeast and Mid-south to prevent economic losses (Bacheler and Mott 1997; Layton et al. 1997,1998; Leonard et al. 1997, 1998; Roof and DuRant 1997; Smith 1997,1998).

Currently, no precise economic injury levels or action thresholds have been established for boll feeding Lepidopteran pests on Bt cotton. Therefore, the objective of this study was to quantify the effects of boll injury during the first four weeks of flowering as an initial effort to help define the point at which economic injury occurs during each of those weeks.

Materials and Methods

Transgenic Bt cotton (cv. NuCOTN 33^{B}) containing the Bollgard™ gene (Monsanto Co., St. Louis, MO) was planted 7 May 1997 and 6 May 1998 at the Macon Ridge location of the Northeast Research Station near Winnsboro, LA. Fertilization rates and general agronomic practices from Louisiana Cooperative Extension Service recommendations were used across the test area to maintain uniformity of all plots. Injury from native insect pest infestations was suppressed with weekly applications of insecticides at the recommended rates prescribed in the Louisiana Insect Control Guides (Bagwell 1997, 1998).

Plots consisted of 3 rows (40 in. centers) x 10 ft. One non-planted border row was maintained between plots to reduce plant damage when workers moved between plots. The plant density on the center row of each plot was thinned to 2 plants per row ft. (26,136 plants/acre) within 2 weeks

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after plant emergence. Treatments were placed in a split-plot arrangement within a randomized complete block design with 4 replications. The main-plot factor consisted of week of flowering and included each of the first four weeks. Boll injury treatments were applied during July in 1997 and 1998 (Table 1). The first week of flowering was determined to be when 50% of plants in each plot across the test area had at least 1 flower or boll. The sub-plot factor consisted of boll injury levels and included 0, 2.5, 5, 10, 20, 40, and 80% injury to the total boll population.

Selection of bolls for mechanical injury was based on their position in the plant canopy and proximity to the mainstem. During each week, every effort was made to injure the most valuable bolls on the plants. Those bolls lowest in the plant canopy and at the first positions on fruiting branches were always selected for injury. At injury levels ^{3}20%, bolls higher in the plant canopy, at more distal fruiting positions, and occasionally on vegetative branches, also were injured.

Total boll populations on the center row of the plots for each respective week of flowering were recorded 1 d prior to boll injury. Those bolls selected for injury were tagged with yellow snap-on-tags (A. M. Leonard Co., Piqua, OH). A hole was drilled completely through the selected bolls using a Black and Decker® cordless drill (model no. 2236) and metal bit (0.25 in. diameter) to simulate boll injury by late (^{3}L4) instar Lepidopteran larvae. Treatments were applied independently to plots so that each plot was damaged only once.

Crop development was monitored weekly throughout each experiment by recording nodes above white flower (NAWF) in each plot until all plots reached NAWF 5. Crop maturity based on percent open bolls was recorded prior to defoliation. Plots were hand-harvested from 19-26 Sep and 18-29 Sep during 1997 and 1998, respectively, to determine seedcotton weights. Boll injury level was plotted against percent open bolls and seedcotton yield within each respective week of flowering. Individual regression equations within each week of flowering were tested for significant relationships using regression analysis PROC REG (SAS Institute Inc. 1989).

Results

Cotton plants showed the ability to compensate for moderate levels of boll injury during the first four weeks of flowering in 1997 and 1998. Nodes above white flower data did not suggest an adverse affect on crop development during any week in 1997 or 1998 until NAWF 5. During 1997, the regression equation did not show a significant relationship between injury level and percent open bolls during weeks 1 (P=0.813) and 2 (P=0.960) of flowering. Boll injury during each of those weeks did not significantly affect crop maturity (Fig. 1). The regression equation did show a significant negative relationship between injury level and percent open bolls during weeks 3 ($P<0.001$) and 4 ($P<0.001$) of flowering. Boll injury during weeks 3 and 4 of flowering significantly delayed crop maturity. Percent open bolls ranged from 73-41% and 72-12% for 0-80% injury levels during weeks 3 and 4 of flowering, respectively. The regression equation did not show a significant relationship between boll injury levels and seedcotton yield during weeks 1 (P=0.407) and 2 (P=0.211) of flowering in 1997 (Fig. 2). There was a significant negative relationship between boll injury level and seedcotton yield during weeks 3 (P=0.011) and 4 ($P<0.001$) of flowering which indicates significant yield reductions at selected boll injury levels during weeks 3 and 4 of flowering.

During 1998, the regression equation did not show a significant relationship between injury level and percent open bolls during weeks 1 (P=0.738) and 2 (P=0.133) of flowering (Fig. 3). There was a significant negative relationship between injury level and percent open bolls during weeks 3 (P=0.001) and 4 ($P<0.001$) of flowering. A significant delay in crop maturity was observed for boll injury levels during each of those weeks. Percent open bolls ranged from 81-47% and 87-26% during weeks 3 and 4 of flowering, respectively, for 0-80% boll injury levels. Boll injury during the first 4 weeks of flowering did not significantly affect seedcotton yield in 1998 (Fig. 4).

Boll injury produced variable levels of yield reductions during each of the first 4 weeks of flowering in 1997 and 1998. The only significant reductions in yield occurred in 1997 during weeks 3 and 4 of flowering. Yield was reduced by 5, 5, 8, 6, 8 and 16% for injury levels of 2.5, 5, 10, 20, 40 and 80%, respectively, during week 3 of flowering in 1997 (Table 2). Boll injury levels of 10, 20, 40 and 80% caused 5, 8, 12 and 32% reductions in yield, respectively, during week 4 of flowering. Although yield losses ranged from 0-7, 11-19, 1-9 and 0-21% for weeks 1, 2, 3 and 4 of flowering, respectively, seedcotton yield was not significantly reduced by any level of boll injury in 1998 (Table 3).

Discussion

Current thresholds for boll feeding cotton pests in most states are static and do not change based on variations in crop value or changes in production costs. This study attempted to define the point at which economic injury by boll feeding pests occurs during each of the first four weeks of flowering. Measurements of crop development throughout the season based on nodes above white flower did not suggest an adverse affect on crop maturity. However, crop maturity, based on percent open bolls, was significantly delayed during weeks 3 and 4 of flowering in both years and resulted in the harvestable crop being in the field longer than that for undamaged plants. When maturity is delayed, the crop becomes more susceptible to numerous late-season pests. Delays in crop maturity could also affect the risk of rain damage to fiber quality (Brook et al. 1992).

These data suggest that low levels of boll injury from insect pests during the flowering period did not have a significant effect on yield. Cotton plants showed the ability to compensate for relatively high levels of damage without a significant reduction in yield. The amount of damage applied to a plot only rarely resulted in an equivalent level of seedcotton loss. The most severe yield losses occurred later in the flowering period during weeks 3 and 4 of flowering.

These data are an initial effort at developing a base of information on economic injury levels for discrete periods during the peak flowering period. This information in turn will allow for the development of dynamic treatment thresholds that change during the season. This will be important for future reference with proper insect pest management on transgenic Bt cotton and with the introduction of newer, more expensive insecticides.

Acknowledgments

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Table 1. Boll injury application dates for each week of flowering during 1997 and 1998.

	Week of flowering			
Year	1	2	3	4
1997	11 July	18 July	25 July	31 July
1998	2 July	9 July	16 July	22 July

Table 2. Percent yield loss for selected boll injury levels applied during the first 4 weeks of flowering during 1997.

Percent	Week of flowering			
boll injury	1	2	3	4
0	-	-	-	-
2.5	1	6	5	1
5	7	11	5	0
10	9	12	8	5
20	0	6	6	8
40	0	13	8	12
80	10	11	16	32

Table 3. Percent yield loss for selected boll injury levels applied during the first 4 weeks of flowering during 1998.

Percent	Week of flowering			
boll injury	1	2	3	4
0	-	-	-	-
2.5	4	19	1	12
5	2	11	2	0
10	7	16	3	3
20	1	12	9	7
40	0	12	7	6
80	5	13	8	21

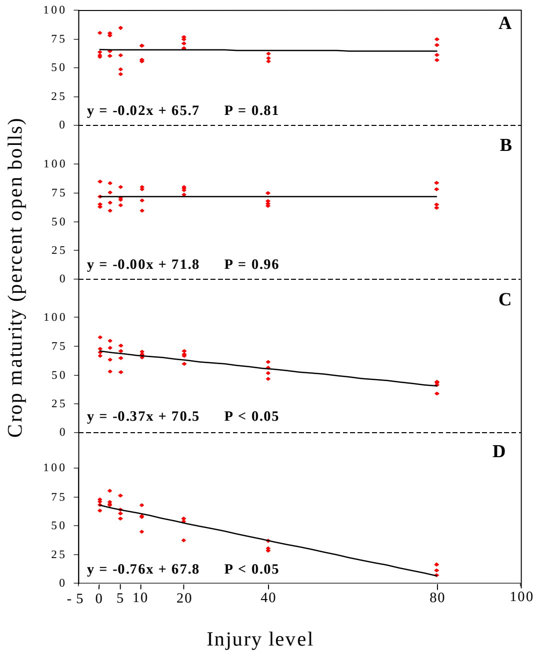

Figure 1. Effects of selected levels of boll injury on crop maturity during the first 4 weeks of flowering in 1997 (A = Week 1, B = Week 2, C = Week 3, D = Week 4).

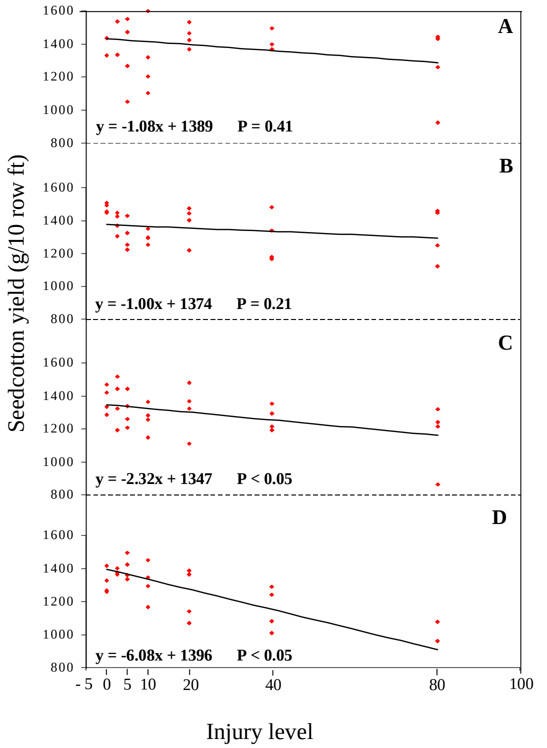

Figure 2. Effects of selected levels of boll injury on seedcotton yield during the first 4 weeks of flowering in 1997 (A = Week 1, B = Week 2, C = Week 3, D = Week 4).

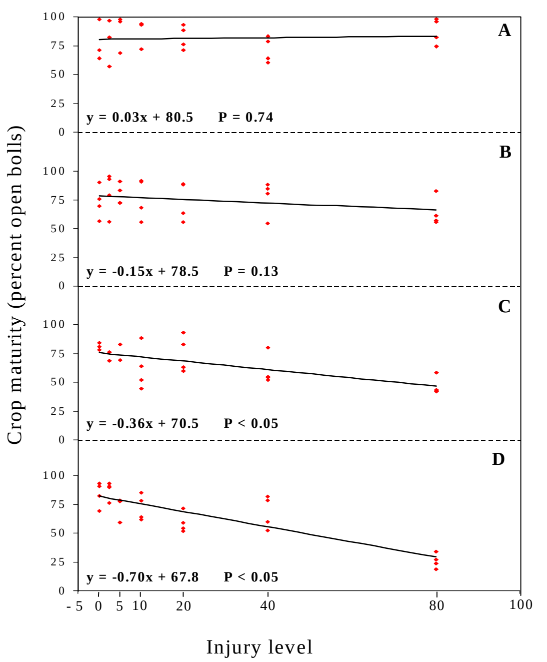

Figure 3. Effects of selected levels of boll injury on crop maturity during the first 4 weeks of flowering in 1998 (A = Week 1, B = Week 2, C = Week 3, D = Week 4).

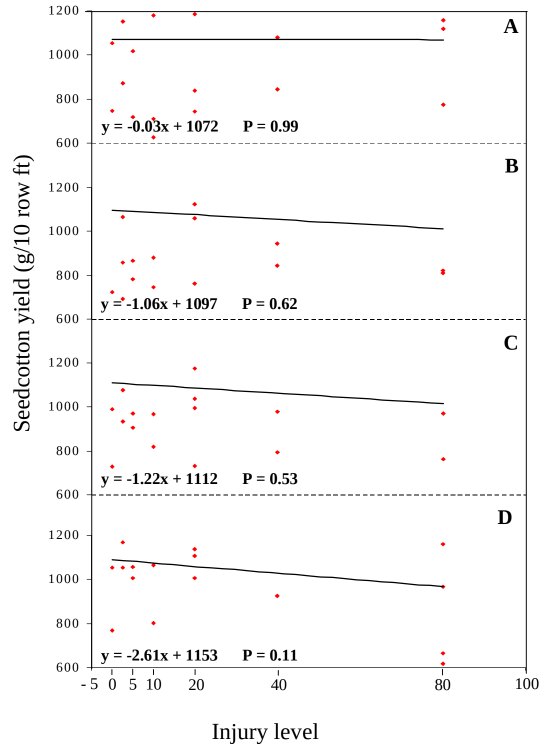

Figure 4. Effects of selected levels of boll injury on seedcotton yield during the first 4 weeks of flowering in 1998 (A = Week 1, B = Week 2, C = Week 3, D = Week 4).