FIELD COMPARISON OF BOLLGARD™ AND BOLLGARD™II COTTONS

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Abstract

Field studies were conducted at three locations in Mississippi in 2000 and one location in 2001 to determine the advantages of cotton expressing two insecticidal proteins of *Bacillus thuringiensis* over cotton expressing only one *Bt* toxin. In 2000, five total insecticide applications for heliothines were required for all locations, but only in non-*Bt* plots. In 2001, four applications were needed (one location), but as in 2000, only in non-*Bt* plots. There was no difference in yield between non-*Bt*, single-toxin, and dual-toxin *Bt* cotton for experiments. Insect pest populations were relatively light in both years of the experiment, resulting in no advantage of Bollgard II cotton over the original Bt cotton technology. In 2000, the cost of *Bt* cotton technology exceeded the cost of foliar insecticides; thus, non-Bt cotton would have been more profitable than either of the *Bt* cottons, due to similar yields. In 2001, however, since there was an increased number of insecticide applications for lepidopteran pests in non-*Bt* cotton, Bt cottons were more of a cost-effective alternative.

Introduction

The heliothine complex (i.e. – tobacco budworm and bollworm) are very damaging pests in cotton on a yearly basis (Williams 2001). Bollgard™ cotton (Monsanto Co., St. Louis, MO) was introduced in 1996, for the control of pink bollworm and bollworm/budworm complex. This transgenic cotton, genetically modified to express the Cry1Ac toxin from *B. thuringiensis* (*Bt*), has been beneficial to producers by reducing foliar insecticide treatments, increasing crop yields and preserving beneficial arthropod populations (Van Tol and Lentz 1998). *Bt* cotton has been found to be very effective against certain pests (e.g.-- heliothines) (Leonard et al. 1998). However, some caterpillar pests are not controlled with this technology alone, and supplemental insecticide applications have been necessary to control armyworms, loopers, and even bollworms under conditions of high population densities (Layton 1998).

To remedy this problem, cotton expressing two insecticidal proteins of *B. thuringiensis* has recently been developed (Bollgard™ II--Monsanto Co., St. Louis, MO). This transgenic cotton expresses not only the Cry1Ac toxin in the original *Bt* cotton, but also an additional toxin, resulting from the insertion of a second gene (*cry2Ab*). This novel dual-toxin cotton was developed to provide substantial control of armyworms, loopers, and bollworms, as well as aid in resistance management.

It is important to research the additional advantages Bollgard II provides over the original *Bt* cotton technology (i.e. insect control, yield improvement, reduction of supplemental insecticide applications). Understanding these advantages can help growers value this new technology.

Materials and Methods

Field experiments were conducted at three locations in Mississippi in 2000 (Starkville, Brooksville, Raymond) and one location in 2001 (Starkville) (Figure 1). Near-isogenic varieties including non-*Bt*, single-toxin, and dual-toxin cotton were compared for heliothine numbers, numbers of occasional lepidopteran pests, damaged squares, damaged bolls, number of insecticide applications, numbers of other pests, beneficial arthropod populations, and seed cotton yield. In 2000, varieties used were DP50, DP50B, and MON15985 for non-*Bt*, single-toxin, and dual-toxin varieties, respectively. Varieties used in 2001 were DP5415 (non-*Bt*), NuCOTN33B (single-toxin), and NuCOTN33BII (dual-toxin). In 2000, three plots of each cultivar were planted on 16 May in Starkville, 22 May in Brooksville, and 25 May in Raymond, all replicated three times (latin square design). In 2001, three plots were planted on 26 April in Starkville as a randomized complete block design, replicated four times. In 2000, plots were 24 rows x 15 m in Brooksville, and 16 rows x 15 m at Raymond and Starkville. In 2001, plot size was 12 rows x 15 m. All plots were planted on 96-cm row spacing.

For each variety (treated separately), insecticide applications were made for control of all pests based on average insect numbers, using insect control recommendations for Mississippi (Layton 2001). When the treatment threshold for a given pest was reached, an insecticide application was made to that variety. When justified, insecticide treatments for caterpillars were either 76 g ai/ha spinosad (Tracer®, Dow Agrosciences), 34 g ai/ha cyhalothrin (Karate®, Syngenta), or 37 g ai/ha cyfluthrin (Baythroid®, Bayer). Treatments for non-caterpillar pests include 336 g ai/ha acephate (Orthene®, Valent) on 14 June and 109 g ai/ha pymetrozine (Fulfill®, Syngenta) on 30 June in Brooksville (2000), both applications for cotton aphids. No insecticide applications were made for non-lepidopteran pests in Starkville in 2000. In 2001, acephate (336 g ai/ha) was applied for tarnished plant bugs on 14, 19, and 25 June. An additional application for aphids/tarnished plat bugs included 45 g ai/ha imidacloprid (Provado®, Bayer) on 9 July. In Starkville, test plots were furrow irrigated five times in 2000 and twice in 2001.

Field Data

In order to determine relative efficacy of the different cultivars under field conditions, naturally occurring populations of pests were monitored using visual, sweep-net and drop-cloth sampling techniques. Visual samples consisted of examining 25 plant terminals per plot for bollworms/budworms on each sampling date. Also examined were 25 squares and 25 bolls per plot for presence of caterpillar pests (particularly heliothines and fall armyworms) and associated damage. On most sampling dates, twenty-five sweeps with a 38-cm diameter sweep net were made in each plot in 2000 and 2001. Two drop-cloth samples (1.8 m of row) were also taken in each plot. Beneficial arthropods were also sampled using sweep-net and drop cloth, including ants, lady beetles, minute pirate bugs, big-eyed bugs, lacewings, and nabids. Pest species monitored with drop cloth/sweep-net include beet armyworms, loopers, tarnished plant bugs, and stink bugs. Samples were usually taken twice weekly.

Seed cotton yields were estimated by harvesting the center two rows of each plot on 27 September in Starkville, 10 October in Brooksville, and 28 October in Raymond. In 2001, test plots were harvested on 28 September (Starkville).

All data were analyzed using analysis of variance procedures and using linear contrasts for mean separation (α=0.05, Proc GLM, SAS 1998).

Results and Discussion

Lepidopteran Pests

The only lepidopteran pests that occurred in sufficient numbers to evaluate the impact of *Bt* cottons on their populations evaluation were heliothines (2000 and 2001) and fall armyworms (2000 only). For heliothines, there was no interaction due to location with respect to variety in 2000 ($p>0.05$). More heliothines were found in non-*Bt* cotton than in either single or dual-toxin cotton, but there was no difference between either *Bt* cotton (Table 1). In 2001, more heliothines were found in non-*Bt* cotton than in either of the transgenic varieties. Once again, there was no difference between single and dual-toxin varieties (Table 1).

With fall armyworms, a similar trend was observed as with heliothines fewer larvae were found in both *Bt* cotton varieties than in non-*Bt* cotton (Table 2).

Damage Due to Lepidopteran Pests

There was no location*variety interaction for heliothine damage in 2000 ($p<0.05$). Single-toxin cotton was no different than non-*Bt* or dual-toxin cotton with respect to heliothine damage, but the single-toxin variety did have more damage than the dual toxin cotton ($p<0.05$) (Table 3). In 2001, more heliothine-induced damage to squares and bolls was found in non-*Bt* cotton than in plots containing either the single or dual-toxin *Bt* cottons (Table 3), but there was no difference between Bollgard or Bollgard II cottons.

Beneficial Arthropod Populations

The only beneficials in that occurred in high enough numbers were big-eyed bugs (*Geocoris* spp.) and lady beetles (primarily *Hippodamia* spp.). There was no significant difference in populations of lady beetles or big-eyed bugs between non-*Bt*, Bollgard, or Bollgard II varieties in either year (Tables 5 and 6). There was also no difference between varieties in total number of beneficial arthropods (Tables 5 and 6).

Insecticide Applications

In 2000, insecticide applications for heliothines were necessary only in non-*Bt* cotton plots, due to light insect pressure. In Starkville, two applications of spinosad were made on 12 July and 29 July, and one application cyfluthrin was made on 5 August. In Brooksville, one spinosad application was made for heliothines on 28 July. In Raymond, one application of cyhalothrin was applied for heliothines on 10 August.

In 2001, heliothine thresholds were broken four times during the growing season. Insecticide applications made include two applications of spinosad (ca. $28-30/A) on 25 June and 9 July, and two applications of cyfluthrin (ca. $16-18/A) on 22 and 29 July. As in 2000, only non-*Bt* cotton was treated for caterpillar pests.

Yield
There was no significant difference in seed cotton yields between non-*Bt*, Bollgard, and Bollgard II cotton in either 2000 or 2001 (Table 6). Yields were between 1900 and 2200 lbs/A in 2000 and between 2280 and 2460 lbs/A in 2001.

Summary

Insect pest populations were relatively light in both years of our experiment-- thus, there was no advantage of Bollgard II cotton over the original Bt cotton. In 2000, the cost of *Bt* cotton technology exceeded the cost of foliar insecticides. Therefore, non-Bt cotton would have been more profitable than either of the *Bt* cottons, due to similar yields. In 2001, since there was an increased number of insecticide applications for lepidopteran pests in non-*Bt* cotton, Bt cottons were more cost-effective.

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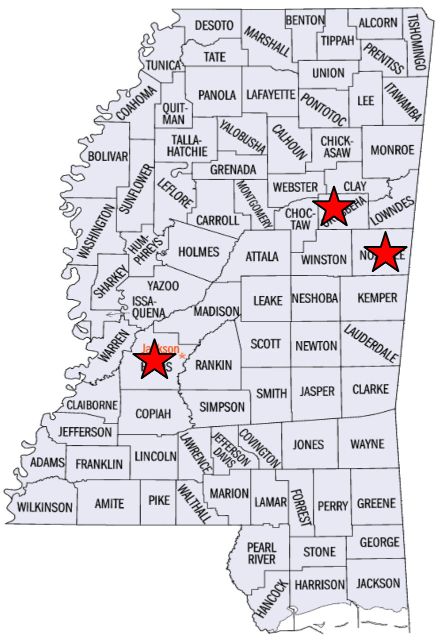

Figure 1. Three locations of *Bt* cotton field experiments in Mississippi.

Table 1. Percent budworms/bollworms found for visual samples in 2000 and 2001.

	% Heliothines	
Variety	**2000**	**2001**
Non-*Bt*	1.4 a	3.5 a
Bollgard	0.1 b	0.7 b
Bollgard II	0.0 b	0.3 b

Means in the same column not followed by a common letter are significantly different (P<0.05, Proc GLM, LSmeans, SAS Institute 1998).

Table 2. Fall armyworm damaged bolls, boll bracts, and total larvae in bolls for samples in 2000.

	%		
Variety	**Damaged bracts**	**Damaged bolls**	**Total larvae**
Non-*Bt*	16.7 a	2.0 a	2.7 a
Bollgard	8.0 b	2.7 a	0.7 b
Bollgard II	2.7 b	0.0 a	0.0 b

Means in the same column not followed by a common letter are significantly different (P<0.05, Proc GLM LSmeans, SAS Institute 1998).

Table 3. Percent damaged terminals, squares, and bolls due to budworms/bollworms found in squares and bolls (combined) for 2000 and 2001.

	% Heliothine damage	
Variety	**2000**	**2001**
Non-*Bt*	6.0 a	7.2 a
Bollgard	2.3 ab	1.2 b
Bollgard II	1.0 b	0.4 b

Means in the same column not followed by a common letter are significantly different (P<0.05, Proc GLM, LSmeans, SAS Institute 1998).

Table 4. Average number of beneficial arthropods found per 25 sweeps and 2 drop cloths in all samples in 2000.

Variety	***Hippodamia* spp.**	***Geocoris* spp.**	**Total beneficials**
Non-*Bt*	3.75 a	0.48 a	11.18 a
Bollgard	3.89 a	0.47 a	11.66 a
Bollgard II	3.83 a	0.57 a	10.79 a

Means in the same column not followed by a common letter are significantly different (P<0.05, Proc GLM, LSmeans, SAS Institute 1998).

Table 5. Average number of beneficial arthropods found per 25 sweeps and 2 drop cloths in all samples in 2001.

Variety	***Hippodamia* spp**	***Geocoris* spp.**	**Total beneficials**
Non-*Bt*	2.68 a	0.58 a	4.13 a
Bollgard	2.43 a	0.47 a	4.10 a
Bollgard II	2.73 a	0.35 a	4.21 a

Means in the same column not followed by a common letter are significantly different (P<0.05, Proc GLM, LSmeans, SAS Institute 1998).

Table 6. Seed cotton yields from field experiments in 2000 (three locations) and 2001 (one location).

	Yield (lbs)	
Variety	**2000**	**2001**
Non-*Bt*	1902 a	2433 a
Bollgard	2196 a	2455 a
Bollgard II	1917 a	2281 a

Means in the same column not followed by a common letter are significantly different (P<0.05, Proc GLM, LSmeans, SAS Institute 1998).