AN ECONOMIC EVALUATION OF BOLLGARD® II COTTON IN WEST TENNESSEE

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Abstract

2003 was the first year of commercial release of the Monsanto's Bollgard® II cotton varieties. Bollgard II cotton hopes to deliver superior lepidopteran insect control over its Bollgard predecessor. The Bollgard II cotton contains the same Bt gene, *Cry1Ac*, as Bollgard, plus an additional Bt gene, *Cry2Ab*. These two genes working together should improve control of all caterpillar insect species in the Cotton Belt. This study evaluated the efficacy of Bollgard II when compared to Bollgard and non-Bollgard sister lines. This study also evaluated each plot for lint yield, lint quality and net return on investment. The research conclusions show improved caterpillar insect control as well as comparable lint yield and quality. Although the results of this study show Bollgard II to be a superior product, more testing will be needed across a wide array of study acres in order to completely determine the efficacy and cost effectiveness of Bollgard II.

Introduction

Monsanto has commercially marketed Bollgard cotton since 1996 (Allen 1999). Bollgard cotton includes a single gene from a bacterium, *Bacillus thuringiensis*. This single gene is referred to as *Cry1Ac*. *Cry1Ac* has a high level of toxicity to many lepidopteran insects but it has proven to be less effective against others. Specifically Bollgard cotton has provided excellent control of tobacco budworms, *Heliothis virescens*, and the pink bollworm, *Pectinophora gossypiella*. Bollgard cotton has been less effective in controlling bollworms, *Helicoverpa zea*, and loopers, *Pseudoplusia includes* (Micinski and Walterman 2000) fall armyworms, *Spodoptera frugiperda*, and beet armyworms, *Spodoptera exigua* (Stewart and Knighten 2000) when compared to budworms. The reduction of control in some worm species has led to over sprays of Bollgard cotton with pesticides to control the worm escapes.

The main reason farmers plant Bollgard cotton is to reduce insect costs per acre and increase profits per acre. Currently, in Tennessee, farmers pay about $24 per acre for planting Bollgard cotton. The actual cost will vary somewhat depending on location, cotton variety and seed size. Monsanto collects this as a technology fee. The grower expects to gain excellent control of budworms and good control of bollworms; these are the two main caterpillar pests in cotton fields in Tennessee (Stewart 2003). The primary advantage of Bollgard cotton is the continuous nature of its insect control. It also helps reduce the quantity of pesticides used, as farmers are purchasing insect control "up front" in the seed's genetics. Unfortunately, Bollgard has not proven to be universally effective for all worm problems.

Bollgard has no activity on the black cutworm, *Agrotis ipsilon* or the variegated cutworm, *Peridroma saucia* (Johnson, 1995 pp.26-27). It is very effective in controlling bollworms and budworms prior to bloom. After first bloom the efficacy of Bollgard against bollworms is greatly compromised. High pressure from armyworms may lead to damage of squares, blooms and bolls. Additionally, low expression of the toxin in some plant parts, such as in pollen and petals, has been implicated in increased survival of the bollworms on Bt cotton (Stewart et al 2001).

Because of the drawbacks from Bollgard cotton, Monsanto introduced Bollgard II commercially in 2003. Bollgard II cotton contains the same *Cry1Ac* gene as the Bollgard, but Bollgard II has an additional gene, *Cry2Ab*. Testing in prior years indicated that the combination of these two genes improves efficacy on target species as well as aids in resistance management (Akin et al.2002.) In Tennessee, Bollgard II cotton costs an additional $8 per acre over Bollgard. This translates to roughly $32 per acre for caterpillar insect control paid at planting. Results from previous years show that greater efficacy of Bollgard II increases retention of early boll set and may promote an earlier harvest. However, because of strict EPA guidelines, the Bollgard II varieties have never been harvested for yield under commercial conditions. Bollgard II plots have been studied for insect control then destroyed in the fall or harvested in small plots under strict guidelines.

Materials and Methods

A field study was conducted in West Tennessee during 2003 on a Grenada Silt Loam soil in Crockett County. The experiment was designed as a randomized complete block consisting of four treatments and three replications. Treatment replications consisted of cotton genotypes DPL 521 (non Bollgard sister line), DPL 215 (Bollgard), DPL 424 (Bollgard II) and DPL 424 (Bollgard II) over sprayed. Each plot consisted of twelve rows planted on thirty-eight inch middles. One row was skipped between each plot in order to avoid larval movement among genotypes. Final plot design was as follows: 521, 424 sprayed, 215, 424, 215, 424, 424 sprayed, 521, 424 sprayed, 521, 424 and 215.

All plots were planted on May 26 in a no-till environment. *Thiamethoxam* (Cruiser 5 FS, Syngenta Crop Protection, Inc., Greensboro, NC) was applied as a seed treatment at 7.65 fl oz/cwt for control of early season thrips. *Acephate* (Orthene 97, Valent USA Corp., Walnut Creek, CA) was applied at .75 lb. a.i. per acre as a mid-season over spray on August 9 for control of plant bugs and stink bugs, as well as to eliminate natural enemies of bollworm. The 424 Bollgard II over spray was administered on August 18 using *lambda cyhalothrin* (Karate Z 2.08 CS, Syngenta Crop Protection, Inc., Greensboro, NC) at 0.04 lb. a.i. per acre. Weed control, fertilization, plant growth regulation and defoliation were achieved by following University of Tennessee extension guidelines.

Weekly insect scouting was conducted for each individual plot. Worm egg, bollworm larva and fall armyworm larva numbers were achieved by examining one hundred consecutive plants, at two random locations, per plot. Examining one hundred consecutive bolls, at three random locations, per plot, derived Boll damage ratings. Maturity ratings examined twenty consecutive plants, at three random locations, per plot.

All data were subjected to ANOVA using PROC GLM (SAS Institute 1990), and means for each treatment were separated ($P \leq 0.05$) using Fisher's Protected Least Significant Difference test.

Each plot was scouted weekly after emergence and all plots were scouted separately. Scouting procedures followed guidelines set by the University of Tennessee Extension Service (Stewart and Lentz 2003.) During weekly scouting, all insects were recorded including harmful and beneficial insects. Careful attention was given to identification of lepidopteran pests, including visual sightings of moths, egg lay and larvae.

After performance of scouting procedures, decisions were made each week to determine if insects were at threshold levels. If insects were above economic threshold, then a spray was administered to the entire research area. Careful attention was given to restrict pesticide chemistry to those that had no effect on lepidopteran insects. The exception to this rule was the overspray of the three Bollgard II plots as discussed earlier.

Each research plot was harvested on November 4, 2003. Each plot's weight was recorded in pounds of seed cotton per acre; Monsanto furnished a boll buggy with weigh scales. Plots of like varieties were put into the same cotton trailer to be evaluated for grade. Treatments were subjected to ANOVA using PROC GLM (SAS Institute 1990), and means for each treatment were separated ($P \leq 0.05$) using Fisher's Protected Least Significant Difference test.

Results and Discussion

Plot effects of cotton genotype characterized differences in numbers of damaged bolls. The non-Bollgard cotton variety had an average damage rating of sixteen percent. This was significantly higher than the Bollgard and Bollgard II cottons damage ratings at eight percent and three percent, respectively (Table 1). The dual-gene construct of the Bollgard II genotype significantly reduced the number of boll damage below that of the single-gene Bollgard variety as well. The Bollgard II over spray treatments had no significant difference of boll damage when compared to the non-sprayed Bollgard II.

Concentrations of eggs laid in different genotypes were not significantly different throughout the growing season. However, bollworm larval counts in the non-Bollgard genotype were significantly higher than the Bollgard and Bollgard II cottons (Table 2). There were no significant differences between the Bollgard and Bollgard II genotypes with respect to bollworm larva.

Numbers of fall armyworms larva found in the non-Bollgard and Bollgard genotypes were significantly higher than the Bollgard II cotton (Table 3).

Node above cracked boll counts found no significant differences among any genotypes during the October 3 or October 8 ratings. However, the October 15 node above cracked boll rating found the Bollgard II to be significantly higher than either the Bollgard or non-Bollgard cotton.

No significant differences with respect to yield or return on investment were apparent among all genotypes.

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Table 1. Estimated mean numbers of worm damaged bolls produced under moderate populations by non-Bollgard, Bollgard and Bollgard II cotton genotypes averaged across three replications in West Tennessee, 2003.

Genotype	**Mean**
Non-Bollgard	15.78 a
Bollgard	7.78 b
Bollgard II	3.2 c

Means with the same letter are not significantly different, Fisher's Protected LSD ($P \leq 0.05$)

Table 2. Estimated mean number of bollworm larva produced under moderate populations by non-Bollgard, Bollgard and Bollgard II cotton genotypes averaged across three replications in West Tennessee, 2003.

Genotype	Mean
Non-Bollgard	11 a
Bollgard	4 b
Bollgard II	1 b

Means with the same letter are not significantly different, Fisher's Protected LSD ($P \leq 0.05$)

Table 3. Estimated mean number of fall armyworm larva produced under moderate populations by non-Bollgard, Bollgard and Bollgard II cotton genotypes averaged across three replications in West Tennessee, 2003.

Genotype	Means
Non-Bollgard	5 a
Bollgard	3 a
Bollgard II	0 b

Means with the same letter are not significantly different, Fisher's Protected LSD ($P \leq 0.05$)

Table 4. Lint yield of non-Bollgard, Bollgard and Bollgard II cotton genotypes averaged across three replications in West Tennessee, 2003.

Genotype	Means
Non-Bollgard	900 a
Bollgard	962 a
Bollgard II	962 a

Means with the same letter are not significantly different, Fisher's Protected LSD ($P \leq 0.05$)