Economic Evaluation of Short Season Bollgard® Cotton Cultivars on the Texas High Plains

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ABSTRACT

An economic evaluation was conducted on near isolines of cotton cultivars that did or did not contain Bollgard® technology for their usefulness in the defense of cotton bollworms *Helicoverpa* (=*Heliothis*) *zea* (Boddie), tobacco budworms *Heliothis virescens* (F.) and other insect pests at a northern and southern location of the Texas High Plains. The most intense insect pressure came from beet armyworms *Spodoptera exigua* (Hubner), an insect not targeted for Bollgard® control, in the southern location. Conventional insecticide applications saved an average 178 lb/ac of lint cotton, but were not economically feasible because of the cost and number of insecticide applications. The northern location did not result in any insect pest surpassing the economic threshold, especially those targeted for control with Bollgard®. The benefits of preventing secondary pests outbreaks from cotton aphids and other pests did not present itself in the two years and two locations of this study.

KEYWORDS: Cotton, Economics, Lint yield, Bollgard®, Insecticides, Bollworms, Budworms, Beet armyworms

Bollgard® cotton has been genetically modified to incorporate a recombinant DNA construct from the bacterium *Bacillus thuringiensis* Berliner subsp. *kurstaki* (Bt), which codes for δ-endotoxin proteins (Perlak et al. 1990, 1991). *Bacillus thuringiensis* is a naturally occurring soil bacterium that when ingested by certain lepidopteron larvae, is a safe alternative to controlling insect pests of cotton while reducing insecticide use and preserving beneficial insects (Armstrong et al. 2000). When ingested, *B. thuringiensis,* a crystalline protein (protoxin), is activated in the insect midgut, releasing toxic fragments that interact with the larval midgut epithelium, binding specifically to the brush border membrane vesicles (Gill et al. 1992). In susceptible insects, gut paralysis and cessation of feeding occur within minutes following ingestion of the δ-endotoxin protein (Dulmage et al. 1978).

Transgenic cotton varieties containing *Bacillus thuringeinsis* (Bt), have been available since 1996 for indeterminate varieties grown in the mid-south and southeast (Williams 1996), but shorter season, stripper-type varieties utilized on the Texas High Plains have only been available with the Bt technology since the 2000 growing season. In 1996, the first year of commercial availability, Bt cotton accounted for 1.85 million acres of total planted U.S. cotton acres (Williams 1997). By 1998, Bt cotton accounted for over a quarter of the total harvested U.S. cotton acres (Frisvold et al. 1999). Due to the lack of stripper varieties more suited for growing on the Texas High Plains, which accounts for approximately 40% of total U.S. cotton production, only an estimated 10% of the total Bt cotton acreage in the U.S. for the 2000 production season was produced on the Texas High Plains (Carpenter and Gianessi 2001).

Short season, stripper-type varieties with Bt have been in production for a short period of time on the Texas High Plains, therefore, there is limited information on fiber quality and lint yields. Efficacy evaluations for target lepidopteran pests within Texas have been positive in terms of controlling insect pests and preserving beneficials (Benedict et al. 1996). It should be pointed out that during the course of a normal production season; the southeastern cotton growing regions have higher lepidopterous insect pressure compared to the Texas High Plains.

The target insects that Bt cotton has provided effective control of on the Texas High Plains is the cotton bollworm *Helicoverpa (=Heliothis) zea* (Boddie) and the tobacco budworm *Heliothis virescens* (F.) complex, and in far West Texas the pink bollworm *Pectinophora gossypiella* (Saunders) Outside of these insect pests, Bt cotton does not control other insects such as thrips (Thysanoptera), boll weevils *anthonomus grandis* Boheman, cotton aphids *aphis gossypii* Glover, cotton fleahoppers *Pseudatomoscelis seriatus* (Reuter) and Lygus *Lygus* spp.

The Bt technology has been widely accepted on the Texas High Plains even though the economics of adoption have not been fully evaluated. The average number of insecticide applications for bollworm control is one per season (Rummel et al.1986). Therefore, the cost of the Bt technology would need to be less than the cost of one application of insecticide on average to justify the cost of the technology. Technology fees, loss of the ability to retain seed for the next year due to exclusive rights of the technology, and up-front costs of seed are some of the economic disadvantages associated with Bt cotton varieties. Ultimately, an economic evaluation of various cotton varieties grown at different locations and under different insect pressures would help in determining the cost-benefit ratios of Bt cotton production on the Texas High Plains.

Historically, the cotton bollworm, *Helicoverpa zea* (Boddie) and the tobacco budworm, *Heliothis virescens* (Fabricius) have caused less damage on the Texas High Plains than in other areas of the state (Rummel et al. 1986). Although the number of insecticide applications per acre may not be as high in the Texas High Plains as compared to other cotton production regions in the United States, the use of Bt cotton varieties may be an economical and safe means of controlling the bollworm/budworm complex.

The objectives of this research were to monitor the seasonal infestation levels of bollworm/budworms, boll weevils, secondary insect pests and beneficial insects in conventional stripper varieties versus newly released isolines of Bt stripper varieties; and to determine if the technology would pay for itself versus managing insects with conventional insecticides. All production costs, including the technology fees for Bollgard® and Roundup Ready®, and boll weevil eradication fees were used versus the return from lint yield and fiber quality as affected by insect damage.

MATERIALS AND METHODS

The cotton isolines used in this study are adapted to Texas High Plains growing conditions. Varieties with Bollgard® and Roundup Ready® technologies were compared to varieties with only the Roundup Ready® technology (Table 1). A northern experimental site near Halfway, TX in Hale County was used to evaluate 2200RR versus 2280BGRR and 2326RR versus 2326BGRR. The cultivars were planted in a randomized block design with four replications under a center pivot irrigation system. A more southern location near Denver City, TX in Gaines County was used to evaluate the previously mentioned cultivars with the addition of 9903RR and 4892BGRR, which are more intermediate cultivars that have a history of producing acceptable yields in more southern counties of the Texas High Plains. Four replications of each cultivar were planted at each site in a randomized block that included a split-plot where each cultivar was designated as treated or non-treated.

Table 1. Parental background of cotton cultivars containing the Bollgard® and Roundup Ready® technology and evaluated in 2000 and 2001.

Parental Background	Herbicide Resistance Trait[1]	Cry1Ac[2] + Herbicide Resistance Trait
HS200[3]	PM 2200RR	PM2280BG\RR
HS26[3]	PM2326RR	PM2326BG\RR
ST474[4]	ST4793RR	ST4892BG\RR

[1]Roundup Ready®; Monsanto Co., (St. Louis, MO).
[2]Bollgard®; Monsanto Co., (St. Louis, MO).
[3]Paymaster® variety (Delta & Pineland Co., Scott MS).
[4]Stoneville Pedigree Seed variety (Memphis, TN).

The treated designation implied that when any pest insect was determined to exceed the economic threshold, an insecticide application of choice would be used to control the insects versus non-treated plots where no control measures were used. Each plot was scouted according to the guidelines described by Sansone et al., 2000. Adult pheromone traps for beet armyworms, bollworms and budworms were placed at the perimeter of each location to monitor the movement of adults around the area. Sampling of the test plots started at emergence but economic pests were scouted on a weekly basis when fruiting structures appeared on the cotton plants.

Test plots were harvested with a two-row or four-row cotton stripper depending upon the availability of harvest equipment. Seed-cotton weights were taken with automated weigh buggies in the field. Sub-samples of seed cotton were ginned at the Texas A&M Experiment Station, Lubbock, Texas. Lint quality was determined by HVI analysis for micronaire, length, and strength characteristics for each sub-sample by the International Textile Center, Texas Tech University, Lubbock, Texas. Cotton yield data were analyzed using Proc ANOVA and means separated by Fishers LSD (SAS 1998). Statistical interactions for Bollgard® versus non-Bollgard®, insecticide treated versus non-treated, and the genetic background of the cotton varieties were also determined in the analysis of variance procedure.

An economic evaluation of the various varieties and insecticide treatments was made using returns above direct cash costs. The market price for cotton lint was estimated using the Daily Price Estimator System (DPES) for West Texas cotton for the 2000/2001 crop year. The DPES is based on an econometrically derived hedonic pricing equation that calculates the estimated premiums and discounts for various lint quality characteristics and adjusts the estimated base price to calculate the market price for cotton lint (Ward et al. 2002). Cottonseed value was based on $95/ton. Production expenses for seed, technology fees, herbicides, insecticides, fertilizer, irrigation, and crop insurance were based on actual expenditures at each experimental location. The Standardized Performance Analysis Database for the 2000 crop year was used to provide average expenses for labor, fuel, and repairs (Blackshear and Johnson 2001). Ginning expenses were calculated based on a 25% cotton lint turnout ratio.

RESULTS AND DISCUSSION

The first year of this study occurred during an epidemic outbreak of beet armyworms at the Denver City site as is indicative of the number of insecticide applications and the significant interaction for the treated versus non-treated test plots, regardless of the Bollgard® technology (Tables 2 & 3). Beet armyworms are not effectively controlled by Bollgard® cotton, but some suppression has been documented (Luttrell et al. 1999). Only two varieties, PM2280BGRR and ST4793R, from the treated plots resulted in positive returns for 2000 at the Denver City location. All other treatments and varieties resulted in losses ranging from \$16.65 to \$81.19 per acre (Table 3). Average lint yields for the treated varieties in 2000 were significantly higher at 549 compared to 373 lbs per acre for the non-treated varieties. The insecticides used to control beet armyworms are newer and more expensive which accounts for the losses in returns for Denver City in 2000. Another confounding factor at Denver City in 2000 was that ultra low volume applications of malathion were made on a weekly basis throughout the growing season which killed many of the predators of lepidoterous pests but did not control the beet armyworms. This allowed for extraordinarily high densities of beet army worms to develop.

Table 2. Insecticides[1] used in test plots that were treated when the economic threshold was exceeded for Bt and non-Bt cultivars evaluated for bollworm\budworm control, 2000 and 2001.

		Application Date		Application Rate (oz/ac)		
Insecticide	Brand	2000	2001	2000	2001	Cost \$/ac
(Denver City)						
Aldicarb	Temik[2]	5/13	5/27	9.6	9.6	26.56
Emamectin	Denim[3]	7/17		0.15		11.19
Carboxylate	Fury[3]	7/28		0.54		6.35
Emamectin	Denim[3]	7/28		0.13		9.87
Chlorpyrifos	Lorsban[3]	8/9		11.0		7.31
Imidacloprid + Cyfluthrin	Leverage[3]	8/9		0.51 + 0.36		9.72
Carbofuran	Furadan[3]	8/25		1.76		2.19
Emamectin	Denim[3]			0.02		1.63
Acephate	Orthene[2]		7/10		2.5	3.00
Indoxocarb	Steward[3]		7/17		1.6	17.83
(Halfway)						
Aldicarb	Temik[2]	5/27	5/27	9.6	9.6	26.56
Oxamyl	Vydate[4]	7/3		1.14		2.91
Oxamyl	Vydate[4]	7/7		1.14		2.91
Oxamyl	Vydate[4]	8/29		1.52		3.86

[1]Boll weevil eradication applications of malathion ULV at a total cost of \$12.00/ac are not shown in the table but are included in the production costs.
[2] Indicates that all test plots regardless of "treatment" designation were sprayed.
[3] Indicates that only the plots designated as "treated" were sprayed for beet armyworms.
[4] Vydate was used at Halfway for boll weevil control because Hale County was not voted in for eradication until 2001.

The 2001 insect season at Denver City was more normal than the previous year with only two applications of insecticides made in July. The first insecticide application of acephate was for cotton fleahoppers, another insect not affected by Bollgard®. The application of acephate allowed beet armyworm populations to increase because the non-selectivity acephate killed predators of the lepidopterous pests. This resulted in an economic density of beet armyworms which were then treated with indoxocarb.

The 2001 growing season at Denver City was more conducive to cotton production and the yields across all varieties were higher than in 2000. The genetic background for the less determinate varieties such as ST4793 and ST4892 resulted in higher yields than the more determinate varieties as indicated by the significant interaction for genetic background (Table 3). Returns above direct costs ranged from $268 to $480 per acre at Denver City in 2001. The cultivar ST4793R had the highest returns in both years of the study.

Table 3. Mean lint yield[1] for Bt and non-Bt cotton cultivars evaluated for bollworm\budworm control, and economic return in dollars/ac, Western Peanut Growers Farm, Gaines County, TX 2000 and 2001.

		2000		2001	
Cultivar	Treatment Designation	Yield (lb/ac)	Return ($/ac)	Yield (lb/ac)	Return ($/ac)
PM2200RR	T	480 b	(31.89)	992 bcde	357.73
PM2280BGRR	T	582 a	2.46	949 cde	310.99
PM2326RR	T	536 ab	(16.65)	1151 abc	445.10
PM2326BGRR	T	535 ab	(35.51)	941 cde	299.38
ST4793R	T	581 a	2.63	1306 a	480.58
ST4892BR	T	579 a	(25.39)	1267 a	337.66
PM2200RR	UT	343 d	(66.55)	831 e	268.20
PM2280BGRR	UT	387 d	(62.56)	930 cde	318.74
PM2326RR	UT	357 d	(63.48)	989 cde	369.87
PM2326BGRR	UT	381 d	(79.92)	886 de	299.38
ST4793R	UT	363 d	(80.37)	1183 ab	436.88
ST4892BR	UT	408 cd	(78.02)	1266 a	435.21
Denver City 2000		*Df*	*F*	*P>F*	
Genetic background[2]		2	2.2	0.145	
Bt vs no-BT[3]		1	7.52	0.013	
Trt vs no trt[4]		1	156.4	<0.001	
Transg*treat[5]		1	0.01	0.929	
Denver City 2001		*Df*	*F*	*P>F*	
Genetic background[6]		2	25.9	>0.001	
Bt vs no-BT[7]		1	3.76	0.068	
Trt vs no trt[8]		1	2.81	0.111	
Transgene*treat[9]		1	7.45	0.014	

[1] Column means followed by the same letter are not significantly different, LSD *P>0.05*.
[2]Interaction means for ST474, HS26, and HS200 were 543, 513 and 503 lbs/ac, respectively.
[3]Interaction means for Bt versus non-Bt in were 542 and 498 lbs/a, respectively.
[4]Interaction means for treated versus non-treated were 620 and 419 lbs/ac, respectively.
[5]Interaction means for transgenic by treatment, BGRR treated, BGRR non-treated, RR treated, and BGRR non-treated were 643, 440, 597 and 397 lbs/ac, respectively.
[6]Interaction means for ST474, HS26, and HS200 were 550, 451 and 421 lbs/ac, respectively.
[7]Interaction means for Bt versus non-Bt in were 489 and 459 lbs/a, respectively.
[8]Interaction means for treated versus non-treated were 487 and 461 lbs/ac, respectively.
[9]Interaction means for transgenic by treatment, BGRR treated, BGRR non-treated, RR treated, and BGRR non-treated were 451, 467, 523 and 455 lbs/ac, respectively.

Neither bollworms nor budworms, the insects more closely targeted for control with Bollgard® cotton, were an economic threat at Halfway and did not approach the economic threshold 2000 or 2001. The only insecticide applications were for boll weevil in 2000 with oxamyl because Hale County was not in a boll weevil eradication program (Table 4). Mean lint yields were very similar for 2000, with no significant differences across varieties or for treated versus non-treated test plots. This was a good indication that no insect pest threatened yield resulting in no treatment measures. Returns above direct costs in 2000 ranged from $108 to $168 per acre.

Table 4. Mean Lint Yield[1] for Bt and non-Bt cotton Varieties Evaluated For bollworm\budworm Control, and economic return in dollars/ac, Texas A&M Experiment Station, Hale County, TX - 2000 and 2001.

		2000		2001	
Cultivar	Treatment designation	Yield (lb/ac)	Return ($/ac)	Yield (lb/ac)	Return ($/ac)
PM2200RR	T	737 a	152.40	1063 c	347.30
PM2280BGRR	T	735 a	115.42	1073 c	346.84
PM2326BGRR	T	742 a	123.83	1159 a	399.37
PM2326RR	T	721 a	138.13	1113 abc	354.46
PM2200RR	UT	783 a	168.90	1084 bc	362.76
PM2280BGRR	UT	727 a	108.81	1077 bc	345.09
PM2326BGRR	UT	834 a	169.19	1128 ab	375.78
PM2326RR	UT	718 a	136.64	1097 bc	361.08
Halfway 2000		*df*	*F*	*P>F*	
Genetic background[2]		1	0.08	0.783	
Bt vs no-BT[3]		1	0.39	0.543	
Trt vs no trt[4]		1	1.00	0.336	
Transgene*treat[5]		1	0.08	0.780	
Halfway 2001					
Genetic background[6]		1	19.81	<0.001	
Bt vs no-BT[7]		1	3.19	0.099	
Trt vs no trt[8]		1	0.22	0.650	
Transgene*treat[9]		1	0.55	0.471	

[1] Column means followed by the same letter are not significantly different, LSD $P>0.05$.
[2] Interaction means for HS26, and HS200 were 751, and 742 lbs/ac, respectively.
[3] Interaction means for Bt versus non-Bt in were 757 and 737 lbs/ac, respectively.
[4] Interaction means for treated versus non-treated were 731 and 764 lbs/ac, respectively.
[5] Interaction means for transgenic by treatment, BGRR treated, BGRR non-treated, RR treated, and BGRR non-treated were 736, 778, 725 and 748 lbs/ac, respectively.
[6] Interaction means for HS26, and HS200 were 1128, 1078 lbs/ac, respectively.
[7] Interaction means for Bt versus non-Bt in were 1113 and 1093 lbs/ac, respectively.
[8] Interaction means for treated versus non-treated were 1106 and 1100 lbs/ac, respectively.
[9] Interaction means for transgenic by treatment, BGRR treated, BGRR non-treated, RR treated, and BGRR non-treated were 1112, 1106, 1091 and 1094 lbs/ac, respectively.

The results at Halfway for 2001 reflected a more favorable production season compared to 2000. Yields from all varieties and treatments were higher, resulting in returns ranging from $345 to $399 dollars per acre . The genetic background interaction for 2001 was significant for Halfway (Table 4). We believe this is analogous to the Denver City yields in 2001 and the result of a favorable production season with more natural rainfall.

The present study was conducted during years of light bollworm/budworm pressure and one year of outbreak infestations of beet armyworms at the Western Peanut Growers Farm near Denver City location in 2000. The Halfway location on average would require one application of insecticide for bollworm/budworm control, but none were required for 2000 or 2001. We believe that cultivars that contain the Bt technology will yield comparable or better than the parent lines, and provide the benefit of not disturbing natural predators and parasites of the cotton aphids and other insect pests. Cotton aphid outbreaks have been documented in the northern and southern high plains and can be expensive in terms of direct economic loss from feeding (Kidd et al. 1996) and from ginning problems as a result of sticky cotton (Hequet E., N. Abidi 2002). These added benefits did not display themselves in the two years of evaluation, but are benefits from the Bollgard® technology that should be very important as boll weevil eradication culminates.

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