ECONOMIC ANALYSIS OF GENETICALLY ENGINEERED BT COTTON FOR TOBACCO BUDWORM AND BOLLWORM CONTROL

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Abstract

The objective of this study was to compare the cost of conventional control of tobacco budworms and cotton bollworms with the cost of genetically engineered Bt cotton. Tobacco budworm and bollworm control expenditures reported by Tennessee farmers in a 1997 survey were used to estimate the cost of conventional control. The cost of conventional control was compared with the costs of two Bt cotton production scenarios using break-even analysis. Bt cotton was not a profitable alternative to conventional control under typical infestation levels; however, in years of heavy infestation, Bt cotton may be a viable alternative to conventional insect control methods.

Introduction

In Tennessee, cotton production accounted for 25 percent of the total value of crops in 1995 and 20 percent of the total value of crops in 1996 (Tennessee Department of Agriculture). Hence, protecting yields by controlling cotton insects is of vital importance. Cotton insects cost Tennessee producers $34 million in 1995 and $23 million in 1996 in revenue lost in yield damage and insect control costs. In 1995, 700,000 acres of cotton were planted, 660,000 acres were harvested, 600,000 acres were infested with either boll worms or tobacco budworms and roughly 475,000 acres were treated for boll worms or tobacco budworms. With an average of three applications made per acre at an average cost of $12 per acre, these worms cost cotton farmers $17 million in application costs and an estimated 11 percent reduction in yield (Williams, 1996). A technological advancement that would allow producers to reduce the number of sprays, hence reducing cost without a reduction in yield, would give producers an economic advantage over current control practices.

In 1996, a genetically engineered cotton, Bollgard®, became available for commercial use. Monsanto genetically engineered a toxic strain of cotton by transferring a Bt (*Bacillus thuringiensis*) gene into a cotton plant. Even though Bt cotton was developed to control the tobacco budworm and bollworm and has been shown to decrease the number of sprays, under heavy infestations some additional insecticide sprays may be required to get satisfactory control, especially for the bollworm; however, the number of sprays should still be less than the number of sprays for non-Bt cotton under the same conditions. Regardless of whether Bt cotton needs additional sprays, the total number of applications should be reduced and when the number of applications of insecticides is reduced, insects are not exposed to chemicals as frequently; hence, they will not develop resistence as rapidly.

Because of concern by regulators about the potential for buildup of insect resistance to Bt, the Environmental Protection Agency required Monsanto to develop resistance management plans which producers must implement. The first part of this two-part plan requires that Bt cotton carry enough toxin to kill any feeding insect which will prevent surviving insects from mating with each other and increasing the resistance to Bt. In the event some insects survive, the second part of the resistance plan includes refuges which are plots of non-Bt cotton planted near the Bt cotton. These plots are to provide a source of tobacco budworms/bollworms that has not been exposed to Bt to mate with any moths that might survive on Bt cotton. This plan should slow any increase in Bt resistance. There are two refuge methods from which cotton producers can choose. The first is an 80/20 split where for each 80 acres of Bt cotton planted, the producer must plant 20 acres of non-Bt cotton. The 20 acres can be treated with conventional foliar insecticides to control cotton insects but can not be treated with Bt products. The second refuge alternative is a 96/4 split where for each 96 acres of Bt cotton planted, 4 acres of non-Bt cotton must be planted and can not be treated with any insecticides for tobacco budworms or bollworms.

Objectives

Farmers are uncertain about the costs and benefits of Bt cotton compared with conventional control. The objective of this study was to evaluate the cost of conventional control of tobacco budworm and bollworm compared with the cost of Bt cotton.

Data and Methods

Data from a 1997 survey of cotton producers in Tennessee (Edens, *et al.*) and partial budgeting were used to evaluate tobacco budworm/bollworm yield damage and control costs. A mailing list of 2,237 cotton producers in Tennessee was developed from data provided by the Cotton Board and the Milan Experiment Station (Fraser 1996; Bradley, 1996).

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Following general mail survey procedures outlined by Dillman, a questionnaire was mailed to cotton producers in March 1997. Even though the main emphasis of the survey was boll weevil control costs and damage, data were provided on control costs and estimated yield losses for all cotton insects. Farmers were queried on cotton production practices and insect control methods, including acres planted, harvest yields, lint prices received, percent yield damage due to all insects, percent yield damage due to the boll weevil, the three ranking insects that caused the most damage, the chemical used to combat these insects and the number of applications. The total number of responses was 800 (34 percent) and of those, 258 provided usable data.

Based on data received from respondents, producers' conventional control costs in 1994, 1995, and 1996 for the bollworm/tobacco budworm, including a variety of selected chemicals and application frequencies, were determined. (These costs did not incorporate estimated yield losses attributed to bollworms and tobacco budworms.) The per-acre costs of using Bt cotton included a $32 per acre technology fee and $1.50 per acre seed premium (Tennessee Farmers Cooperative, 1996). These costs were calculated for two planting scenarios as required by the Environmental Protection Agency. The per-acre costs of the first scenario (80/20) were estimated by adding 80 percent of the Bt cotton costs to 20 percent of the estimated conventional insect control costs. The per-acre costs of the second scenario (96/4) were equal to 96 percent of the Bt cotton costs.

Survey responses from West Tennessee were divided into two regions, north and south, to determine if a difference existed based on location. Those counties included in the south were: Shelby, Fayette, Hardeman, McNairy, Hardin and Tipton in their entirety, and that portion of Haywood County lying south of the Hatchie River. The remaining counties in West Tennessee were included in the north. It was hypothesized that producers in southwestern Tennessee incurred higher control costs than their northern counterparts. Once the cost of Bt cotton was established, two break-even analyses were performed comparing them to the weighted average cost of conventional control for each region and year.

Survey respondents were asked to report estimated yield and insect damage for boll weevils and all cotton insects but because respondents did not give estimates of yield damage caused by bollworms and tobacco budworms, an estimated maximum potential yield was determined based on the assumption that producers suffered no insect damage. Maximum potential yield was defined as yield in the absence of all cotton insects other than boll weevils. It was calculated using the harvested yield damage estimates for cotton insects other than boll weevils as provided by farmers in the survey. When conventional control costs were less than the cost of Bt cotton, the additional yield that Bt cotton would have to produce, over-and-above conventional cotton, to cover the cost difference was determined. Once this break-even yield was determined, it was compared to the estimated maximum potential yield to determine if Bt cotton was an economically feasible alternative to conventional insect control. When the break-even yield was larger than the maximum potential yield, Bt cotton was considered unfeasible. If the break-even yield was less than the maximum potential yield, the percentage of acres that could possibly produce the break-even yield was determined by summing the acreage of the respondents in this category.

When conventional control costs were determined to be greater than the costs of Bt cotton, the number of additional chemical treatments that could be applied to the Bt cotton without exceeding the cost of conventional control was determined as well as the percentage of acres that could receive additional applications.

Results

Table 1 presents a comparison of conventional and Bt cotton control costs. The conventional cost results are based on information provided by survey respondents who listed the bollworm tobacco/budworm as one of the top three problem insects for 1994, 1995, and 1996. The 1994 and 1996 growing seasons were considered more typical years for tobacco budworm and bollworm damage in Tennessee and 1995 was labeled a heavy infestation year because it had the largest percentage yield damage from tobacco budworms and bollworms in 12 years (Williams, 1983-1996). Results indicate that most acres would not have benefitted from the use of Bt cotton regardless of the resistance management plan was selected, except in 1995 when infestations were heaviest (Table 1).

In 1995, the average cost of Bt cotton ranged from $32 per acre for the 96/4 resistance plan to $38 per acre for the 80/20 resistant plan. The cost of conventional tobacco budworm and bollworm control ranged from $57 per acre in southwestern Tennessee to $39 per acre in the northwestern Tennessee. Given that 1995 conventional control costs were greater than the cost of Bt cotton regardless of the resistance plan, 69 percent of the planted cotton acres in southwestern Tennessee would have benefitted from Bt cotton, and 44 percent of the cotton acres planted in northwestern Tennessee would have benefitted from Bt cotton. Again, 1995 was a heavy infestation year due to excessive rainfall and a mild winter which caused conventional insect control costs to be much higher than normal in Tennessee. In 1994, producers had average conventional control costs of $16 per acre in southwestern Tennessee and $17 in northwestern Tennessee. Of the acres in our sample, only 6 percent in southwestern Tennessee and 11 percent in northwestern Tennessee had conventional control costs greater than Bt cotton costs. In 1996, producers had below average conventional control costs of $10 per acre in southwestern Tennessee and $13 per acre in northwestern Tennessee. Results indicate that 16 percent of cotton acres planted in southwestern Tennessee would have benefitted from Bt cotton, but only 1 percent of cotton acres planted in northwestern Tennessee would have benefitted from Bt cotton in 1996. These results indicate that conventional control costs for bollworms and tobacco budworms were slightly higher in northwestern Tennessee except for the heavy infestation year, 1995.

Break even yield increases required to equate the cost of Bt cotton with the cost of conventional insect control are presented in Table 2. Under the 80/20 resistance plan, producers in southwestern Tennessee who had 1994 conventional control costs that were less than the cost of Bt cotton would have to observe a 21 lb/acre or more increase in Bt cotton yield to break even with the cost of conventional control. About 32 percent of the cotton acres in the sample had maximum potential yields less than the break-even yields; hence, they could not have achieved the break-even yield increase. The percentage was slightly higher in northwestern Tennessee in 1994 with 44 percent of the acres not being able to produce the break-even yield increase of 19 lb/acre. The break-even yield increase dropped to 3 lb/acre in 1995 in southwestern Tennessee and to 10 lb/acre in northwestern Tennessee. Only 6 percent of the cotton acres in southwestern Tennessee could not have produced these yields compared to 26 percent of the cotton acres in northwestern Tennessee. The break-even yield increase dropped from 1994 levels to 16 lb/acre in 1996 in southwestern Tennessee and increased to 23 lb/acre in northwestern Tennessee. The average percentage of acres that could not have produced the break-even yield increase dropped from 1994 levels in southwestern Tennessee to 19 percent and increased in northwestern Tennessee to 63 percent.

Producers who reported conventional costs less than the cost of Bt cotton under the 96/4 resistance management plan would require a break-even yield increase of 25 lb/acre in southwestern Tennessee and 22 lb/acre in the northwestern Tennessee in 1994. In 1996, the break-even yield increases were 18 lb/acre and 27 lb/acre, respectively. Results in 1995 saw a dramatic drop in the break-even yield increase with only 3 lb/acre in southwestern Tennessee and 12 lb/acre in northwestern Tennessee. In 1995, under the 96/4 plan, only 6 percent of cotton acres could not achieve the break-even yield increase in southwestern Tennessee compared to 30 percent in northwestern Tennessee. In southwestern Tennessee, only 32 percent of the acres in 1994 and 21 percent of the acres in 1996 could not achieve the break-even yield increase under the 96/4 plan. In 1994, 46 percent of the cotton acres in the northwestern Tennessee sample had maximum potential yields that were less than the break-even yield. By contrast, 66 percent of the cotton acres did not produce potential yields greater than the break-even yield value in 1996. Our results indicate that even though the break-even yield required to make Bt cotton profitable was relatively similar across West Tennessee, fewer acres in northwestern Tennessee compared to southwestern Tennessee could have produced the necessary yields under 1994, 1995, and 1996 circumstances.

The percentage of acres that could use Bt cotton and 1 or more insecticide applications and not exceed the cost of conventional control are reported in Table 3. Under the 80/20 resistance plan, only 3 percent of the acres in southwestern Tennessee and 9 percent of the cotton acres in northwestern Tennessee could receive 1 insecticide application and not exceed the cost of conventional control in 1994. None of the cotton acres could use Bt cotton and receive 2 or more insecticide applications and break even with the cost of conventional control. For the 96/4 resistance plan, the percentage of acres that could use Bt cotton and 1 insecticide application was nearly identical to the 80/20 resistance plan. In 1995, when insect pressure was much higher, 23 percent of cotton acres in southwestern Tennessee could use Bt cotton and 1 insecticide application and not exceed the cost of conventional control. Moreover, for 13 percent of cotton acres, more than 5 insecticide treatments could be applied to Bt cotton and not exceed the cost of conventional control. Under the 96/4 resistance plan in 1995, 23 percent and 18 percent of cotton acres in southwestern and northwestern, respectively, could receive more than 5 additional insecticide treatments and not exceed the cost of conventional control. Under the 80/20 resistance plan, in 1996, 7 percent of Bt cotton acres in southwestern Tennessee could receive 2 insecticide treatments and not exceed the cost of conventional control and 4 percent could receive 4 insecticide treatments and not exceed the cost of conventional control. In northwestern Tennessee, only 1 percent of the Bt cotton acres could receive 1 insecticide treatment and not exceed the cost of conventional control. Under the 96/4 resistance plan in southwestern Tennessee in 1996, 7 percent of the Bt cotton acres could receive 3 insecticide treatments and still breakeven with the cost of conventional control and in northwestern Tennessee, 1 percent of the cotton acres could receive 1 insecticide treatment and not exceed conventional control costs.

Overall results indicate that when Bt cotton costs are less than conventional control costs under normal infestations, less than 11 percent of the Bt cotton acres can receive additional applications of insecticide; however, under heavier infestations, up to 59 percent of Bt cotton acres could receive 1 or more insecticide treatments without exceeding the cost of conventional control methods. Given that some studies indicate that Bt cotton is not as effective against the bollworm as it is against the tobacco budworm, this finding indicates that some producers may be able to get satisfactory control for both insects and still remain under the cost of conventional control, especially in years of heavy infestations.

Conclusions

As insect damage continues to warrant repeated insecticide applications, insects will continue to develop resistance to chemicals causing insect control costs to increase. Profitable and effective alternatives to existing methods must be developed. The use of genetically altered cultivars, specifically Bt cotton, is one alternative which should be analyzed to determine its economic feasibility.

Results indicate that for most survey respondents under normal bollworm and tobacco budworm infestation years, Bt cotton was more expensive than conventional control methods. However, under a year of heavy bollworm and tobacco budworm infestation (1995), Bt cotton could be an economical alternative for many producers depending on individual costs and yields. In 1995 when infestations were heavy, average conventional control costs were higher than the costs of Bt cotton regardless of the resistance plan. For this year, a majority of cotton acres in southwestern Tennessee could have benefitted from the use of Bt cotton. These results imply that for areas of the cotton belt with historically heavy bollworm and tobacco budworm problems, Bt cotton could provide a profitable alternative to conventional control methods for most farmers; but, for areas where bollworm and tobacco budworm damage is minimal or infrequent, Bt cotton may prove to be unprofitable for most farmers.

Results indicate that under normal infestations years conventional control costs for the bollworm and tobacco budworm were similar in West Tennessee regardless of location; however, for the heavy infestation year, producers in southwestern Tennessee spent more on control costs. Also, during heavy infestations, a majority of acres in southwestern Tennessee could have benefitted from Bt cotton versus less than half the cotton acres in northwestern Tennessee.

Results indicate that even though the yield required to make Bt cotton more profitable than conventional cotton was relatively similar across West Tennessee, fewer acres in northwestern Tennessee could have produced those yields under 1994, 1995, and 1996 circumstances. This difference across West Tennessee regions could have resulted from a difference in yields and infestation levels, or from differences in seasonal, managerial, marketing or other impacts, all of which should be explored in future research.

Estimated yield damage costs were not included in total conventional costs; however, we did calculate a maximum potential yield loss from survey results based on yield damage from all insects other than boll weevils. Including more precise estimates of these yield damage costs from tobacco budworms and bollworms could increase total conventional costs, making Bt cotton more attractive and more profitable for more acres than indicated. Further research should fully evaluate any possible yield increases of Bt cotton and compare the total costs, including yield differences between the alternatives. In addition, research should evaluate the effectiveness of Bt cotton against the tobacco budworm versus the bollworm and determine the number of additional insecticide sprays that can be utilized without the cost of Bt cotton exceeding the cost of traditional control methods.

Bibliography

Bagwell, Ralph D. 1996. *Managing resistance-what can we do now?* Proceedings 1996 Beltwide Cotton Conferences. Vol 1. January, pp. 118-122.

Bradley, John. Superintendent Milan Experiment Station, 6205 Ellington Drive, Milan, Tennessee 38358.

Edens, Elizabeth R., James A. Larson, Roland K. Roberts, Burton C. English, and Rebecca L. Collins. *Cotton Insect Control in Tennessee: Results of a 1997 Survey of Cotton Farmers.* Department of Agricultural Economics and Rural Sociology, Agricultural Experiment Station, The University of Tennessee, Knoxville, Research Report 97-18, November 1997.

Fraser, David. Director of Communications, Cotton Board, 871 Ridgeway Loop, Ste. 100, Memphis, Tennessee 38120-4019.

Jones, Randy Sherman. 1997. "Evaluation of Bt cottons for heliothine complex control and yield potential in Tennessee." Thesis, University of Tennessee, May.

Layton, Blake. 1997. Ph.D., Extension Cotton Entomology Specialist, Mississippi State University, Web Page, http://www.ces.msstate.edu/pubs/pub2108.htm. August 14.

Lentz, Gary, Nancy B. Austin, and Jennifer M. Bannister. 1994. Department of Entomology and Plant Pathology, Agricultural Experiment Station, The University of Tennessee, Knoxville, Tennessee, Research Report 94-11, July.

Tennessee Farmers Cooperative. 1997. Personal interview with Glennda Meade.

U. S. Department of Agriculture. 1996. *1996 Tennessee agricultural statistics.* National Agricultural Statistics Service.

Wilkins, Thea. 1997. Assistant Professor of Agronomy and Range Science, University of California, Davis, http://www.crop-net.com/archive/cacc397a.htm. August 14.

Williams, R. Michael. 1995. Chairman. Cotton insect losses. Proceedings Beltwide Cotton Conferences, 1996, p. 684.

Table 1. Cost per acre of Bt cotton versus conventional control.

Year	Control Method	Southwestern Tennessee ($/acre)	Northwestern Tennessee ($/acre)
1994	Conventional	16	17
	Bt (80/20)[a]	30	30
	Bt (96/4)[b]	32	32
	% Acres[c]	6	11
1995	Conventional	57	39
	Bt (80/20)[a]	38	35
	Bt (96/4)[b]	32	32
	% Acres [c]	69	44
1996	Conventional	10	13
	Bt (80/20)[a]	29	29
	Bt (96/4)[b]	32	32
	% Acres[c]	16	1

[a]80% Bt cotton acres and 20% non-Bt cotton acres resistance plan.
[b]96% Bt cotton acres and 4% non-Bt cotton acres resistance plan.
[c]Percentage of acres that would have economically benefitted from Bt cotton compared to conventional control methods.

Table 2. Yield increase necessary for Bt cotton to break even with conventional insect control costs for farmers with Bt cotton costsgreater than conventional control costs.

	Southwestern Tennessee		Northwestern Tennessee	
Year	Yield Increase (lb/acre)	Acres[c] (%)	Yield Increase (lb/acre)	Acres[c] (%)
1994				
Bt (80/20)[a]	21	32	19	44
Bt (96/4)[b]	25	32	22	46
1995				
Bt (80/20)[a]	3	6	10	26
Bt (96/4)[b]	3	6	12	30
1996				
Bt (80/20)[a]	16	19	23	63
Bt (96/4)[b]	18	21	27	66

[a]80% Bt cotton acres and 20% non-Bt cotton acres resistance plan.
[b]96% Bt cotton acres and 4% non-Bt cotton acres resistance plan.
[c]Percentage of Bt cotton acres that could not achieve break even yield increases.

Table 3. Percentage of cotton acres that could use Bt cotton plus one or more additional insecticide treatments without exceeding conventional control costs for farmers with Bt cotton costs less than conventional control costs.

	Southwestern Tennessee		Northwestern Tennessee	
Year	Bt(80/20) [a] (% Acres)	Bt(96/4)[b] (% Acres)	Bt(80/20)[a] (% Acres)	Bt(96/4)[b] (% Acres)
1994				
1 tmt	3	3	9	10
2 tmt	0	3	0	1
3 tmt	0	0	0	0
4 tmt	0	0	0	0
5 tmt	0	0	0	0
>5 tmt	0	0	0	0
1995				
1 tmt	23	5	11	8
2 tmt	4	18	6	6
3 tmt	0	4	3	3
4 tmt	13	5	3	1
5 tmt	3	4	10	3
>5 tmt	13	23	8	18
1996				
1 tmt	0	0	1	1
2 tmt	7	0	0	0
3 tmt	0	7	0	0
4 tmt	4	0	0	0
5 tmt	0	0	0	0
>5 tmt	0	0	0	0

[a]80% Bt cotton acres and 20% non-Bt cotton acres resistance plan.
[b]96% Bt cotton acres and 4% non-Bt cotton acres resistance plan.