5. Bt Cotton Plant-pesticides

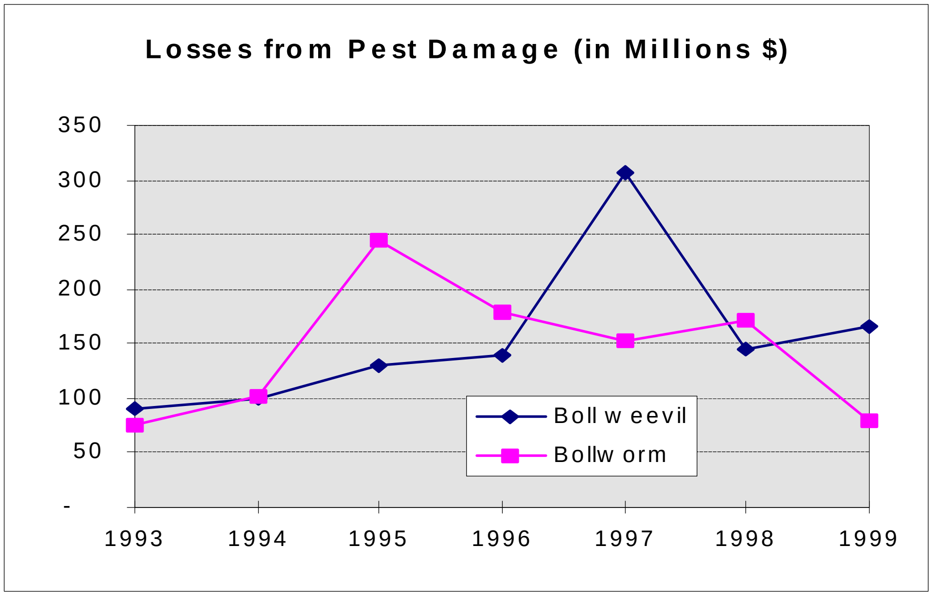
a. Insect Pests and Insecticide Usage

Bt cotton is used to control the cotton and pink bollworm and the tobacco budworm. Other pests where there is some control include the cabbage looper, saltmarsh caterpillar, cotton leaf perforator, and European corn borer (Gianessi and Carpenter, 1999). The bollworm and the tobacco budworm are the major pests controlled by Bt cotton and account for one-fourth of all losses due to pest infestations. Pink bollworm is predominately a pest in Arizona and California. Losses from bollworm show a downward trend since 1995, as contrasted with the boll weevil despite area wide eradication programs. The cotton bollworm and budworm, and the boll weevil continue to be the dominant pests of cotton after Bt seed was introduced in 1996. However, looking at the year by year graph suggest the emergence of a potential downward trend for the Bt susceptible pests.

Average Annual Loss on Cotton

	1993 to 1995		1996 to 1999	
Pest	Acres Infested (000's)	Dollar Loss (000's)	Acres Infested (000's)	Dollar Loss (000's)
Boll/Bud Worms	10,838	140,379	10,156	145,236
Pink bollworm	433	6,713	386	7,032
Total Bt pests	11,271	147,092	10,542	152,268
Boll weevil	7,914	105,851	7,134	189,422
Lygus Bugs	7,114	58,720	6,476	64,106
Cotton Fleahopper	3,252	3,257	4,270	57,010
Aphids	10,737	32,836	8,778	32,724
Thrips, early season	10,582	24,443	10,202	27,157
Stink Bugs	2,332	5,587	2,731	16,385
Spider mites	2,558	22,833	2,486	10,616
Fall armyworms	1,869	3,206	2,069	9,199
Beet armyworm	4,132	44,920	2,948	8,037
Sweet potato Whitefly	818	6,855	486	2,967
European corn Borer	411	2,295	534	1,328
All others	9,281	3,294	8,063	3,068
Non Bt pests	61,001	314,096	56,180	422,018
All pests	72,272	461,188	66,721	574,286

Source: Compiled for National Cotton Council by Mississippi State University (http://www.msstate.edu/Entomology/Cotton.html)



Source: Cotton Board and Mississippi State University

b. Estimating Reductions in Insecticide Use

USDA's Pesticide Impact and Assessment Program has compiled crop profiles that detail pest problems and methods of control (http://ipmwww.ncsu.edu/opmppiap/). Five states have posted profiles for cotton: Alabama, Arizona, North Carolina, Tennessee, and Texas. Predicted reductions in use are highest for states in the deep South, as evidenced by Alabama, where 2-8 applications are replaced by Bt cotton.

State	Relevant Quotes from Crop Profiles
Texas	It is believed that insecticide use has been substantially reduced with the advent of Bt cotton. Growers justify the increased costs of Bt cotton based on fewer insecticide applications. In some times of increased infestation, growers may supplement Bt cotton with an insecticide treatment.
Tennessee	Bt cotton reduces total insecticide applications by 1 to 5 applications

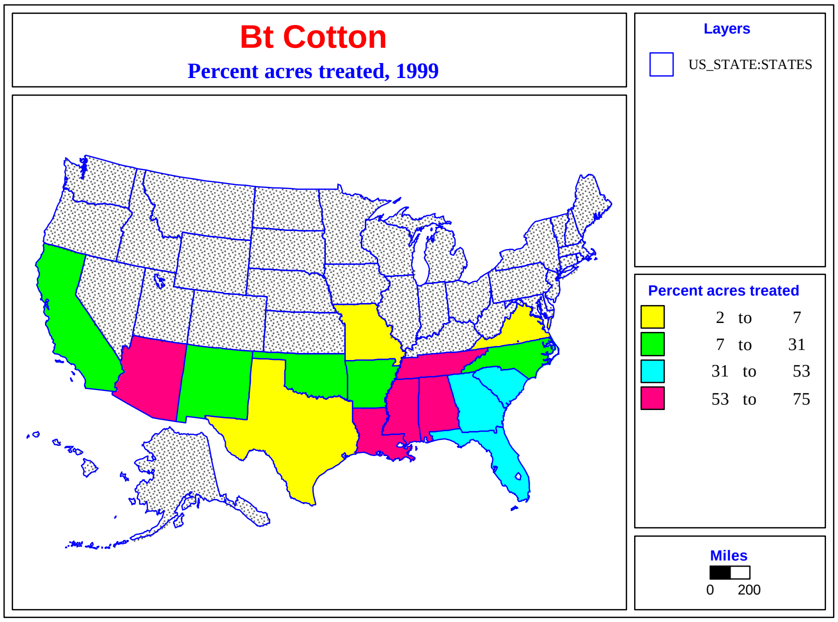
State	Relevant Quotes from Crop Profiles
Alabama	Bt cotton replaces from two to eight or more insecticide applications targeted for bollworms and budworms
Arizona	A substantial proportion of pesticides sprayed on Arizona cotton was for the control of the pink bollworm prior to the introduction of transgenic cotton varieties utilizing genes from *Bacillus thuringiensis*. The pink bollworm is presently being controlled with far fewer conventional insecticide treatments,
North Carolina	An average of 2.6 applications have been targeted toward budworms/bollworms during the past ten years. Nearly all (99 percent) of North Carolina's cotton is treated annually for this complex. [Bt cotton is not discussed, or the potential of Bt cotton to reduce use]

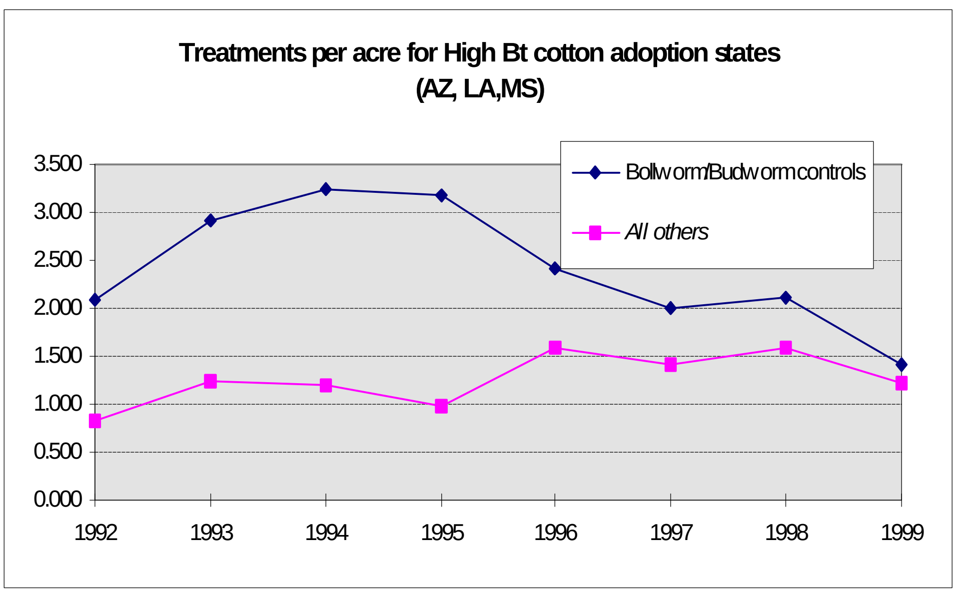
Several econometric models have been used to analyze use reductions. A simple comparison of use between Bt adopters and non-adopters can be misleading because the decision to adopt is affected by the extent of the pest problem. Studies by ERS using data at the grower level (controlled for Bt selection bias) show a reduction in use of conventional pesticides in the Southeast, excluding organophosphate and pyrethroids. (Fernandez-Cornejo and McBride).

EPA's review has used USDA's National Agricultural Statistical Service (NASS) annual surveys of major producing cotton states to identify trends in pesticide use. Unfortunately, the NASS selection of states can change between years. Only 6 of the 12 states have annual data from 1991 to 1999. These are Arizona, California, Louisiana, Arkansas, Texas and Mississippi. These states account for two-thirds of acres planted but only half of the Bt cotton acreage. The trend analysis was conducted by dividing the 6 states into two groups--the high adopters and low adopters. Arizona, Louisiana, and Mississippi have over 60% of planted acreage in Bt cotton by 1999. The low adopter group includes Arkansas, Texas, and California which have less than 20% of cotton planted to Bt cotton. The insecticides were also divided into two groups--ones that are used for the control of Bollworm/Budworm (alternatives to Bt cotton) and all other insecticides. The hypothesis is that the most significant reduction occurs in states with the highest adoption rates, and the pesticides with the most reduction are those that control for the bollworm/budworm.

For those states that have a higher percent of Bt cotton over (60%), the charts do show a significant reduction in treatments per acre. For the alternatives to Bt cotton, use was reduced from an average of 3 treatments per acre to about 1.5. Use of remaining insecticides may have increased slightly, possibly due to the need to now control secondary pests. The reduction due to Bt cotton is estimated to be 1.2 treatments per acre. As expected, it is more difficult to identify a use reduction trend for those states that have a lower than 20% Bt adoption rate. Pesticides that target the budworm/bollworm show a flat trend at 0.4 treatments per acre and a use reduction estimate could not be calculated for these states.

Percent of Cotton Acres Planted with *Bt* Cotton

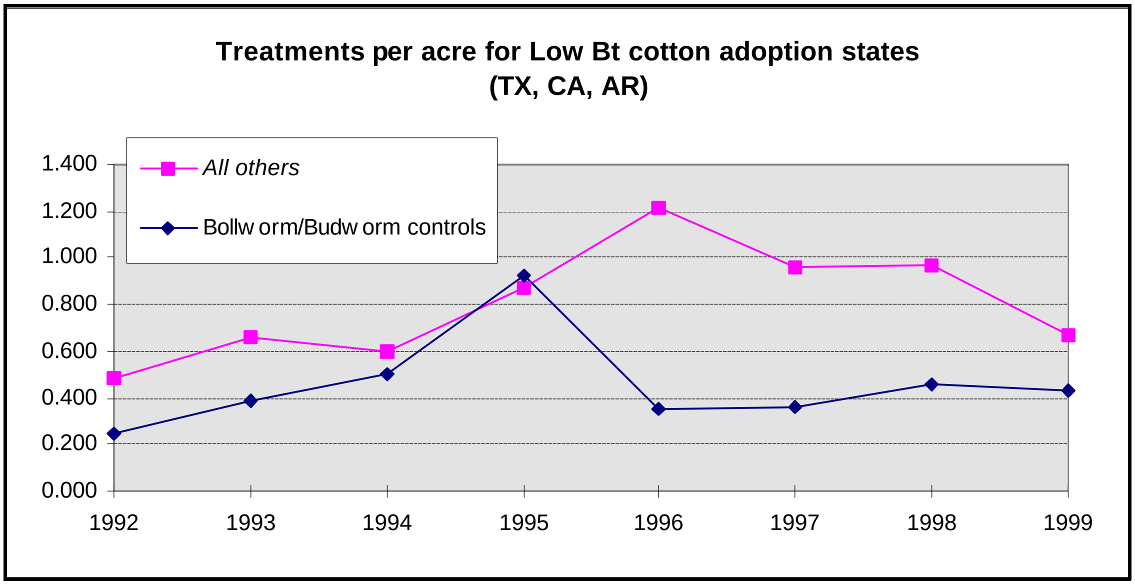




Sources: USDA/NASS for acres planted, National Cotton Council for *Bt* cotton acres.

Source: NASS surveys 1992 thru 1999

Analysis limited to states with NASS survey data for each year (excludes Alabama and Tennessee).



Source: NASS surveys 1992 thru 1999

Estimated Use Reduction by State

	Bt cotton % of planted acres	Reduced use (Millions acres)
Mississippi	62%	1.4
Georgia	47%	1.8
Texas	7%	Not estimated
Alabama	71%	0.7
Tennessee	68%	0.7
Louisiana	62%	0.7
North Carolina	31%	1.1
Arizona	75%	0.3
South Carolina	53%	0.4
Arkansas	18%	Not estimated
California	15%	Not estimated
Oklahoma	29%	0.3
Florida	42%	0.1
New Mexico	18%	Not estimated
Virginia	6%	Not estimated
Missouri	2%	Not estimated
All States	28%	7.5

Sources: NASS, National Cotton Council web site, and EPA estimates

Based on 1.2 acre treatment reduction for high user states, there is a 7.5 million acre treatment reduction associated with Bt cotton. Bollworm/budworm infestations were especially severe in the Southeast in 1995 and insecticides which cotton farmers had relied on may have been showing some insect resistance failure. Including all states surveyed by NASS, treatments per acre planted show a sharp reversal in 1996.

The estimated reduction due to Bt cotton of 7.5 million acres in 1999 amounts to 0.6 treatments per acre, when applied to the 13.3 million acres planted in 1999.

A check on the validity of the use reduction estimates was done using target pest information from Doane Marketing Research, Inc. (1998). Seven (7%) of treatments target the bollworm/budworm alone and 33% of all applications include the bollworm/budworm as one of several pest targets. And the estimated 21% reduction in 1999 is within the range of the percent for which the bollworm/budworm is being targeted. (Adjusting for the 84% coverage of all cotton acres in the 1999 NASS chemical use surveys, the total acre treatments are 28.7 million on

13.3 million acres planted. Using the 7.5 million acre treatments reduction in this review, total acre treatments would have been 36.2 million without Bt cotton, or a 21% reduction.).

c. Human Health Benefits and Environmental Benefits

The estimated use reduction by active ingredient is evaluated with respect to human health and environmental benefits including reducing the number of incidents to terrestrial and aquatic wildlife caused by the top pesticide uses currently responsible for the greatest mortality to such wildlife. Three Bt cotton alternatives involved in aquatic incidents are endosulfan, methyl parathion, and profenofos. In addition, all pyrethroids are highly toxic to fish and aquatic arthropods in laboratory studies under conditions that are not reflected well in the field.

Environmental benefits of reduced use of conventional insecticides associated with Bt cotton

Pesticide	Environmental Benefit to Less Use	Environmental Incident Information System (Top 10 aquatic)
Endosulfan	Could be a big benefit for fish, but not much is used, and rate is not extravagant	yes
Methomyl	EPA generally concerned about the ecological effects to terrestrial wildlife and aquatic organisms	
Methyl parathion	Probably benefit to small birds in general, and big benefit for aquatic arthropods	yes
Profenofos	Current occupational risk assessment indicates risk concerns for aerial mixer/loaders and aerial applicators; Acute risks are of concern for fish; probably benefit for most aquatic organisms, maybe a little to birds	yes
Thiodicarb	Classified as Group B2 carcinogen-probable human carcinogen; EPA generally concerned about the ecological effects to terrestrial wildlife and aquatic organisms	
Cyfluthrin	Reduction in pyrethoid use will provide some benefit to mussels	
Cypermethrin		
Deltamethrin		
Tralomethrin		

Zeta-cypermethrin		

Source: Larry Turner, EPA , OPP, Field and External Affairs Division (2000a and 2000b), Environmental Incident Information System (1999), Pesticide Reregistration Eligibility Decisions (RED's) for Profenofos, Methomyl, Thiodicarb http://www.epa.gov/REDs/ .

Benefits to workers also accrue from reduction in conventional chemical pesticide use. Those mixing/loading and applying pesticides have less exposure and workers who scout for insects, move irrigation equipment, or perform other activities that require them to be in the field will not be exposed to the chemical insecticides replaced by Bt cotton plant-pesticides. Unfortunately, there is not documentation available to the Agency to quantify the amount of risk reduction for workers.

d. Grower Benefit Analysis

Bt cotton plant-pesticides provide the highest per acre grower benefits of all of the Bt crops. The studies available for Bt cotton estimate benefits over a wide range--from $20 million to $161 million dollars per year. One factor which distinguishes the models used in making these predictions is whether market share (adoption rate) of Bt cotton is linked to costs and benefits. Benefit estimates are higher for the cotton studies which used models where there is no linkage. Market share creates an internal reality check by relating product advantages to grower decisions.

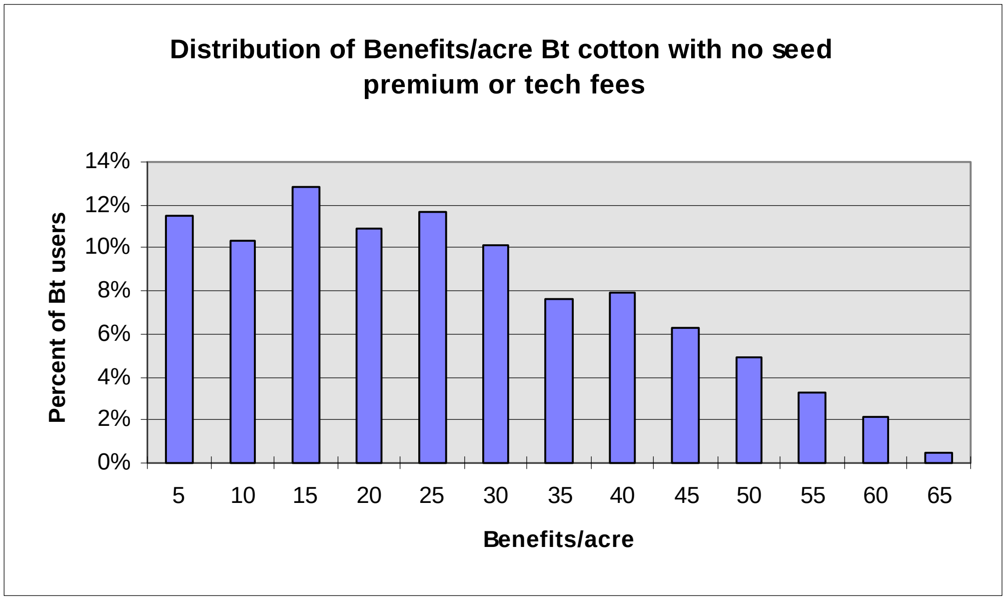
Three studies which use models without linkage estimate benefits between $71.8 and $161.3 million dollars per year (Frisvold, et.al., 1998, Falck-Zepeda, et.al., 2000, Gianessii and Carpenter, 1999). The range of benefits is both lower and narrower when models do link adoption rates to grower decisions (Marra, et.al., 2000, Jorge Fernandez-Cornejo and McBride, 2000). Comparable benefits estimates were not contained in these studies and were extrapolated by EPA to be between $26 to $53 million per year.

Marra, et al., (2000) estimate a demand curve for a new technology, Bt cotton, based on a survey of 300 cotton farmers in four states: Georgia, Alabama, North and South Carolina. The maximum technology fee of $40/acre in the Carolinas and $55/ acre in Georgia/Alabama. At the $25.50 Bt fee in 1999, an implied average benefit of $7.00 to $14.50/acre, which aggregates to $26 to $53 million per year on 3.6 million acres of Bt in 1999.

USDA Economic Research Service, Fernandez-Cornejo, et al. (2000) applied a two stage econometric model to characterize the adoption decision, using grower level data from the Agricultural Resource Management Study (ARMS) for 1996 though 1998. Growers that use Bt seed would be expected to have more severe pest problems in general. The two stage model hopes to separate the characteristics of the Bt cotton user, and to hold them constant while investigating the impact of Bt seed on pesticide use and economic returns. The econometric results estimate the change in pesticide use and economic returns with changes in Bt adoption rates.

EPA applied the USDA/ERS elasticities to the cotton crop budget of Mississippi, a typical southeastern cotton state with a high (37%) Bt cotton adoption rate. The elasticity for revenue increase of 2.1% for a 10% change in adoption, indicates a revenue growth of 7.8% in Mississippi. The increase in net variable profits of 2.2% for a 10% increase in adoption provides a 8.2% growth. The budget implies a savings in chemical costs given the changes in revenues and profits. The implied percent reduction (16.8% to 23.3%) is consistent with the 21% estimated use reduction from NASS data trends. Extrapolating the increase in variable profits per acre for 1997 ($22.56) to national benefits is $47 million on 2.1 million Bt cotton acres in 1997, as reported by the U.S. Cotton Council.

The simple simulation model computes an expected proportion of growers that would select Bt cotton given Bt cost premium (seed plus technology fee), other direct costs unique to Bt cotton, and the direct benefits (yield enhancement, insecticide cost reduction, etc.). Model results appear



Source: EPA, Simple Simulation Model

to be in agreement with actual Bt cotton share of planted acres from 1996 to 1999, USDA/ERS estimates of yield and cost savings, willingness to pay surveys, and reductions in pesticide use predicted from the NASS data.

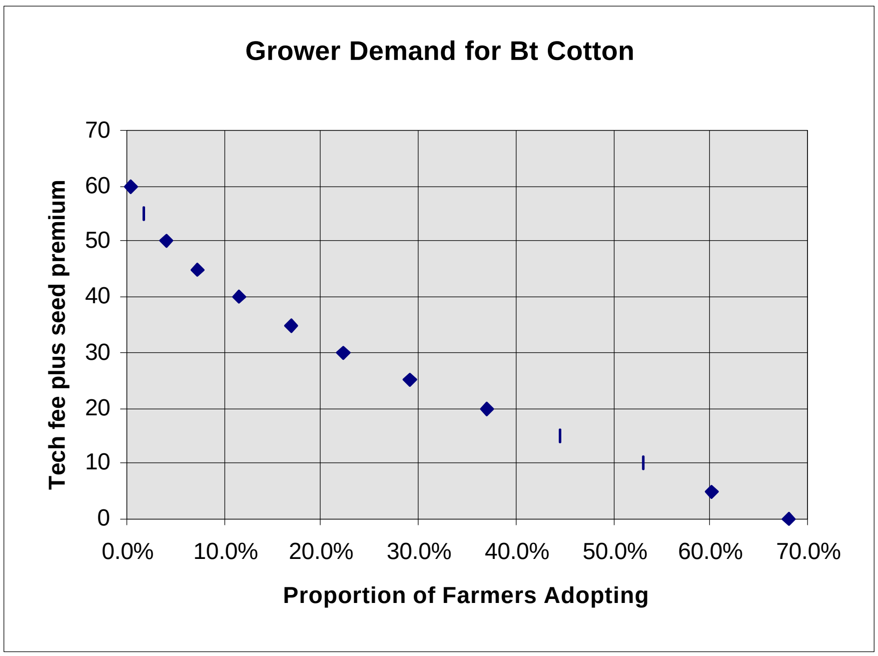
Cotton provided a unique opportunity to test the model since the seed premium declined by $9/acre from 1996 to 1999. A good fit to actual market share is provided by an upper limit benefit of Bt cotton of $64/acre and upper limit cost of $40/acre. Benefits reflect a maximum of 8 fewer acre treatments (at $8/acre), a 16% yield increase (at $400/acre), or some combination of both. The upper limit costs unique to Bt cotton of $40/acre constructs a demand curve that corresponds well to changes in market share as seed premiums have declined. The table below compares the actual percent of US cotton planted with Bt cotton with the predicted model percent output through the years 1996 to 1999. The model predictions are close to actual with average difference is 2%.

Year	Bt cost premium	Actual % of US cotton	Predicted %
1996	$33.45	17%	18.2%
1997	$33.82	21%	17.5%

1998	$29.01	21%	23.3%
1999	$25.50	28%	29.1%

Average grower benefits for 1999 are estimated to be $12.80/acre, at $25.50 cost of Bt cotton. Increases in yield and reduction in chemical cost must cover both the Bt premium ($25.50) and benefits of $12.80 per acre. The range of use reduction is therefore 4.8 treatments (assuming no yield increase) or a 9.6% yield improvement, assuming no use reduction. The estimated 1.2 treatment reduction from NASS data implies a residual yield benefit of 7.2% on average.

The simple simulation model results generally agree with the estimated demand curve by Marra, Calrson, Hubbell (2000) and yield/cost implications of Fernandez-Cornejo, McBride (2000) (USDA/ERS). Demand curves are close to one another. The USDA/ERS estimate of a 6.2% yield increase on a 28% national Bt adoption rate is also close to the 7.2% residual yield benefit estimated by the simple simulation model.



The grower demand curve derives from the distribution of absolute benefits

Source: EPA, Simple Simulation Model

National Net Benefits using Simple Simulation Model
(Thousands of acres) National Benefits in $1,000's

Year	Planted Acres	Bt cotton	% of US cotton	Benefits/Acre	National Benefits
1996	10,567	1,796	17%	9.05	16,257
1997	9,900	2,079	21%	9.79	20,352
1998	11,840	2,487	21%	10.96	27,252
1999	12,805	3,585	28%	12.80	45,894

Source: USDA planted acres, Cotton Council for Bt cotton, EPA benefit estimates

Summary of Estimated Grower Benefits

Title/Author	Methodology	Grower benefits			
		‘96	‘97	‘98	‘99
Models where adoption rates **are not** linked to benefits and costs		(millions $)			
Adoption of Bt cotton: regional differences in Producer Costs and Returns, University of Arizona, Tucson	Quadratic programming: consumer benefits, program outlays, producer returns adoption ceilings are exogenous	71.8	83.8	88.2	
Surplus Distribution from the Introduction of Biotechnology Innovation, Auburn U.	Simulation model using monopoly pricing power, adoption rates exogenous	161.3			
Agricultural Biotechnology: Insect Control Benefits, NCFAP	Partial Budgeting, adoption rates are exogenous			92.7	
Models where the adoption rates are linked to benefits and costs					
Environmental Protection Agency	Simple Simulation model, equilibrium adoption rate	16.3	20.4	27.3	45.9

Estimating the Demand for a New Technology: Bt Cotton and Insecticide Polices, North Carolina State	Survey of 300 growers. Benefits extrapolated to 1999 acreage Bt cotton, based on willingness to pay.				26 to 53
Genetically Engineered Crops for Pest Management in U.S. Agriculture, USDA, ERS	Econometric model using ARMS data 1997.		47		

Source: Environmental Protection Agency compilation, 2000.