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VALUE OF BT AND HERBICIDE-RESISTANT COTTONS

Janet E. Carpenter and Leonard P. Gianessi
National Center for Food and Agricultural Policy
Washington, DC

Abstract

US cotton growers have adopted *Bt* and herbicide-resistant varieties rapidly since their introduction in the mid-1990's. The benefits to growers include higher yields, lower costs and ease of management. In addition, pesticide use has decreased since the introduction of these varieties.

Introduction

Genetically modified cotton varieties have been adopted rapidly since their introduction in the mid-1990's. By 1999, 60% of the total US cotton acreage was planted to insect and/or herbicide resistant varieties: 32% *Bt*, 45% herbicide resistant and 16% "stacked" varieties with both insect and herbicide resistance (USDA AMS). Understanding the reasons why growers are adopting these varieties is critical in an evaluation of the impact that the introduction of these technologies has had on US agriculture. Here these technologies are viewed in the context of existing pest control options to better understand issues that have influenced grower decisions. Aggregate impacts on growers in terms of yields and costs are estimated, and impacts on pesticide use patterns are observed.

Bt Cotton

Bt cotton varieties were introduced in 1996, providing control of three major cotton insect pests: tobacco budworm, cotton bollworm and pink bollworm. Cotton bollworm and tobacco budworm are prevalent in the Southeast and Mid-South production areas, while pink bollworm infests cotton acreage primarily in western states such as Arizona and California. These varieties offered an alternative to conventional insecticide spray programs. Insecticides were used on 75% of the total cotton acreage before the introduction of *Bt* varieties (USDA NASS). In 1995, the year before *Bt* varieties were introduced, it was estimated that 2.4 insecticide applications on average were made to control bollworm/budworm across all cotton producing states, and that a 4% yield loss was incurred due to these two pests. Tobacco budworm infestations were particularly heavy in 1995, causing severe yield losses in some areas. The worst damage was sustained by Alabama growers, who on average experienced a 29% yield loss due to bollworm/budworm (Williams 1996). These losses were attributed to the ineffectiveness of pyrethroid insecticides against budworm, due to the development of resistant populations in some states.

The adoption of *Bt* varieties was extremely rapid in some areas and has been slower in others. Overall, *Bt* cotton was planted on 13% of US cotton acreage in 1996 (Williams 1997). Adoption has steadily increased, to 17% in 1997, 21% in 1998 and 32% in 1999 (Williams 1998, Williams 1999, USDA AMS). After a year of very high budworm populations and damage in 1995, growers in Alabama adopted the new technology at an extremely rapid rate, planting 77% of total acreage to *Bt* varieties in 1996 (Williams 1997). In 1999, 75% of cotton acreage in Alabama was in *Bt* varieties (USDA AMS). Florida and Mississippi also adopted over 30% in 1996. By 1999, South Carolina was a major adopter, at 84% of total acreage, followed by Alabama, Louisiana, Mississippi and Florida, all of which planted over 60% of total acreage to *Bt* varieties (USDA AMS). Figure 1 shows adoption of *Bt* varieties by state for 1999.

Two major cotton producing states have had very low adoption rates thus far, which skews the national adoption rate. Texas, which accounted for 46% of cotton acreage in 1998, has only adopted *Bt* cotton on a small scale, at only 9% in 1999. Adoption has been hindered by the lack of stripper varieties appropriate for growing conditions in Texas. California also has low adoption rates, due to strict control over which varieties could be grown in the San Joaquin Valley. Demand for *Bt* cotton varieties in California is expected to be relatively low, however, since most producing areas of California are not infested with the three target pests of *Bt* varieties.

For Alabama growers, yield losses due to bollworm/budworm were drastically reduced from levels experienced in 1995. In Central Alabama, where the average yield loss due to bollworm/budworm was 55% in 1995, losses have varied between 2 and 7% from 1996 to 1998. The number of insecticide applications was reduced from 10 to between 0 and 2 (Williams 1996, 1997, 1998, 1999).

The major impact of the adoption of *Bt* varieties is a reduction in insecticide use. Comparing USDA pesticide use data for 1998 to 1995 shows a dramatic reduction in the use of insecticides used to control bollworm/budworm. Table 1 shows reductions in insecticide use for those insecticides that are recommended for bollworm/budworm control. This difference in use was adjusted to account for reduction in planted acreage from 1995 to 1998. The overall reduction in insecticide use for bollworm/budworm is estimated at 2.0 million pounds, or 12% of all insecticides used in those five states in 1995 (Gianessi, et al.). It has been estimated that 2.3 less treatments were necessary for *Bt* acreage compared to conventional acreage, based on survey results from Southern and Southeastern growers in 1998 (Mullins, et al.). Over 4.67 million acres of *Bt* cotton were planted in 1999, which would result in a total reduction of 10.7 million treatments.

Several surveys have found that growers are achieving higher yields and attaining higher profits by planting *Bt* varieties, due to better pest control and decreased insect control costs. The average increase in net returns from nine studies in 11 states comparing *Bt* to conventional varieties was $38/acre, taking into account the technology fee (Gianessi, et al.). Survey results from 109 sites in Southern and Southeastern states in 1998 found that yields were 37 lbs./acre higher for *Bt* varieties (Mullins, et al.). These yield and revenue impacts, if realized over all 4.67 million acres of *Bt* cotton in 1999, would result in a $177.5 million increase in revenues and 173 million lbs. increased cotton production.

Herbicide Resistant Cotton

In 1995, BXN cotton was introduced, which was tolerant to bromoxynil, a post-emergence broadleaf herbicide already registered for use in corn and small grains. Roundup Ready cotton varieties became available in 1997, presenting growers with another option for post-emergence weed control using glyphosate.

Nearly all U.S. cotton acreage is currently treated with herbicides. In 1998, 95% of the U.S. acreage was treated (USDA NASS). The average number of herbicide applications per treated acre was 2.6 in 1995, while 34% of the acreage received 3 or more applications. An average of 2.7 different active ingredients per acre were used in 1995, with 24% of the treated acreage receiving 4 or more active ingredients (USDA ERS). Primary weed species are morningglory (*Ipomoea* spp.), pigweed (*Amaranthus* spp.), nutsedge (*Cyperus* spp.), cocklebur (*Xanthium* spp.) and johnsongrass (*Sorghum* spp.) (Byrd).

Prior to 1995, cotton growers did not have any broadleaf herbicides that could be used over the top of a growing cotton crop that did not have the potential to cause crop injury. Instead, growers would use post-directed applications of nonselective herbicides, and cultivation. Directed post-emergence treatments require weeds to be shorter than the cotton crop and this height differential is sometimes difficult to achieve. Post-directed treatments on small cotton require time-consuming treatments and can damage plants if herbicides contact the plant foliage.

In 1996, a new post-emergence broadleaf herbicide became available for use over the top of growing cotton without causing crop injury. Pyrithiobac (Staple) is a selective broadleaf herbicide that may be applied post-emergence at any stage of crop growth. The first year it was available, it was used on 10% of U.S. cotton acreage, increasing to 23% in 1997 (USDA NASS). By 1998, its use had dropped back to 16%

(USDA NASS), likely due to competition with weed control programs using newly introduced herbicide tolerant cotton varieties.

The adoption of BXN and Roundup Ready varieties has been driven largely by the ease and convenience of avoiding early post-emergence directed herbicide applications, as well as having new tools to control particular weed problems. Along with the introduction of Staple, growers now have three new post-emergence broadleaf herbicides for broadleaf weed control. This is especially valuable in areas where weeds have become resistant to other commonly used herbicides. Figure 2 shows adoption of these three new herbicide technologies. 1999 data on the use of Staple are not yet available.

Bromoxynil controls many broadleaf weeds but does not control grasses, which makes continued use of soil applied herbicides likely. In particular, adoption has been high in some areas due to its effectiveness on morningglory and cocklebur. However, bromoxynil does not provide effective control of sicklepod, which limits adoption in areas where that weed is prevalent. Arkansas has adopted BXN varieties at the highest rate (41% of planted acres), due to low infestations of sicklepod. Tennessee had adopted BXN varieties rapidly, 40% in 1998, but in 1999 reduced their acreage to 10% due to the commencement of boll weevil eradication and the demand for *Bt* varieties (Hayes). BXN varieties have not yet been stacked with the *Bt* trait. Figure 3 shows BXN cotton adoption by state for 1999.

Roundup Ready varieties have been adopted rapidly in some areas. By 1999, South Carolina growers had adopted Roundup Ready varieties on 94% of total planted acreage (USDA AMS), which is believed to be due to the effectiveness of Roundup on DNA-resistant palmer amaranth, and sicklepod (Murdoch). Five other states have adopted Roundup Ready varieties on between 50 and 60% of planted acreage: Florida, Georgia, North Caorlina, Oklahoma and Tennessee (USDA AMS). Figure 4 shows Roundup Ready cotton adoption by state for 1999.

Some growers may have realized cost savings by switching to Roundup Ready programs. While conventional programs may cost around $44 per acre, Roundup Ready programs cost between $23 and $47, including an $8/acre technology fee, depending on the number of applications and whether other soil-applied or post-emergence treatments are made. Staple is relatively expensive, with a program cost of approximately $57/acre. BXN programs cost approximately the same as a conventional program and did not require a technology fee until 1999, which will make it more expensive (Hayes). In field trials of conventional programs with and without Staple compared to BXN and Roundup Ready programs, relative yields and net returns varied. Table 2 shows average relative yields compared to a conventional program from trials conducted in six states in 1997 and 1998. Table 3 shows net returns for Tennessee and Louisiana, including technology fees where appropriate, herbicide costs, costs of cultivation and taking into account differences in lint quality. Though these yield and return results are from few years and locations, at this point there appears to be no clear-cut advantage of one program over another.

Adoption of BXN and Roundup Ready varieties is expected to reduce the total amount of herbicides used in cotton production, due to lower use rates. For conventional programs, application rates between 5.5 and 9 lbs./acre of herbicides are used, compared to 2.75 to 4.5 lbs./acre for Roundup Ready systems and 2.8 to 4.45 lbs./acre for BXN systems (Coble). Indeed, USDA pesticide data shows a declining trend in herbicide use in cotton. The total amount of herbicides used in 1998 was the lowest in the past nine years, which is partially due to declining acreage. Figure 5 shows trends in herbicide use and acreage. Between 1994, the year before BXN cotton was introduced, and 1998, the last year for which there are pesticide use data, 3.6 million lbs. less herbicide was used in cotton, adjusted for the decline in acreage. Similarly, the number of herbicide treatments for cotton has also declined, by 1.775 million acre-treatments from 1994 to 1998, also adjusted for the decrease in acreage. However, at least part of these reductions may be attributable to adoption of Staple, which is used at a low rate.

Summary

The benefits of genetically modifed cotton varieties include yield increases, lower costs and ease of management. Pesticide use has also decreased. Table 4 summarizes the impacts of the introduction of *Bt* and herbicide resistant cotton varieties. Cotton production is estimated to increase by 173 million lbs. Insecticide and herbicide use has decreased by over 2 million pounds the number of pesticide applications has decreased by an estimated 10.7 million acre-treatments. An increase in revenues is estimated at $177.5 million.

Acknowledgements

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Figure 1. ***Bt*** **Cotton Adoption 1999**

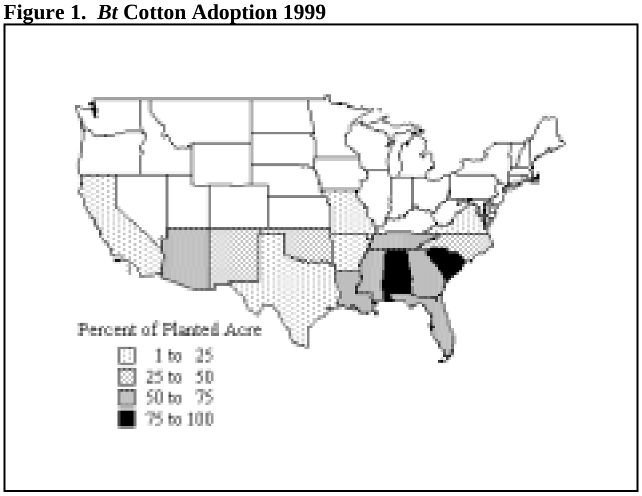
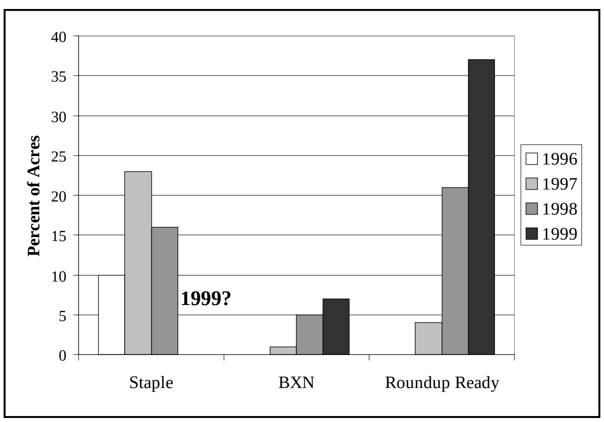


Table 1. Cotton Bollworm/Budworm Insecticide Use Reductions Due to Introduction of Bt Varieties 1995 to 1998 (AR, AZ, LA, MS, TX)

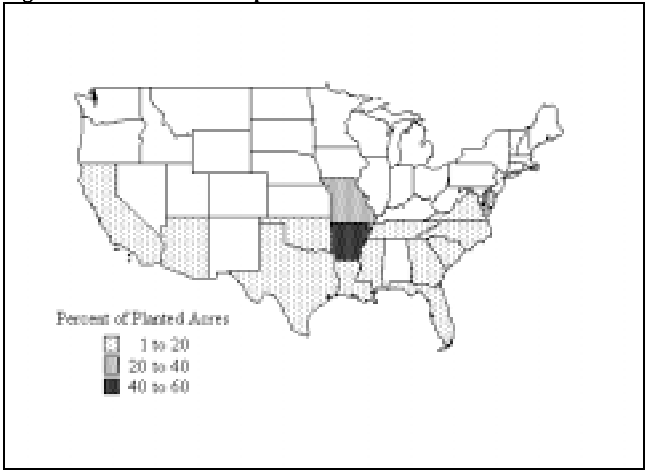
Insecticide	(1,000 lbs.)
Amitraz (Ovasyn)	42
Cyfluthrin (Baythroid)	35
Cypermethrin (Ammo)	81
Deltamethrin (Decis)	-11
Esfenvalerate (Asana)	19
Lambdacyhalothrin (Karate)	58
Methomyl (Lannate)	156
Profenofos (Curacron)	1,014
Spinosad (Tracer)	-19
Thiodicarb (Larvin)	665
Tralomethrin (Scout)	4
Zeta-cypermethrin (Fury)	-1
TOTAL	**2,044**

Figure 2. Adoption of New Herbicide Technologies



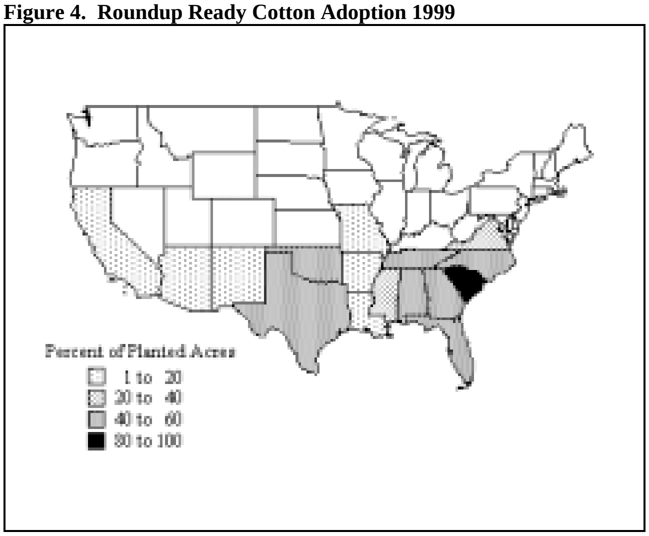
USDA NASS; USDA AMS

Figure 3. BXN Cotton Adoption 1999



USDA AMS

Figure 4. Roundup Ready Cotton Adoption 1999



USDA AMS

Table 2. Average Relative Yields for Conventional, BXN and Roundup Ready Programs for FL, GA, LA, MS, NC, and TN 1997-1998

Weed Control Program	Yield Relative to Conventional Program
Conventional	100%
Staple	95%
BXN-Buctril	93%
RR-conv.+1xRU	101%
RR-Treflan/RU	102%
RR-RU/Bladex+MSMA	93%
RR-RU as needed	96%

Brecke, Bridges, Hayes, Miller, Snipes, Wilcut

Table 3. Comparison of Net Returns for Tennessee and Lousiana 1998 ($/acre)

Program	TN	rank	LA	rank
Conventional	541	4	522	6
Staple	491	7	559	2
BXN-Buctril	494	6	668	1
RR-conv.+1xRU	636	1	546	4
RR-Treflan/RU	636	2	536	5
RR-RU/ Bladex+MSMA	535	5	556	3
RR-RU as needed	569	3	508	7

Hayes, Miller

Figure 5. Cotton Acreage and Herbicide Use (AR, AZ, CA, LA, MS, TX)

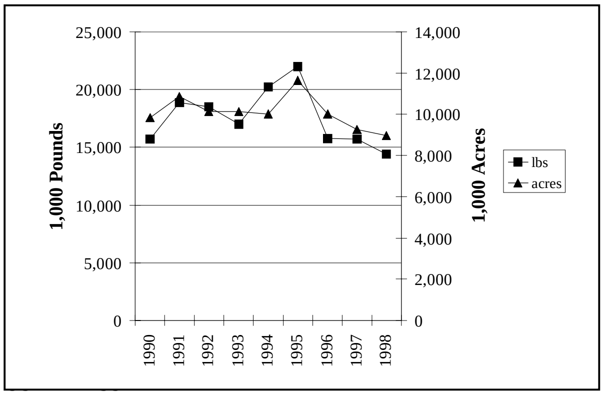


Table 4. Summary of Impact of Introduction of Genetically Modified Cotton Varieites

Benefit	Impact
Increased Cotton Production	173 million lbs.
Reduced Pesticide Use	2 million lbs.
Fewer Pesticide Treatments	10.7 million acre-treatments
Increased Revenues	$178 million