Agricultural Biotechnology:
Updated Benefit Estimates

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Executive Summary

U.S. farmers have adopted genetically modified crop varieties rapidly since their introduction. By 2000, roughly one fifth of U.S. corn acreage, over half of the soybean acreage, and almost three-quarters of the cotton acreage was planted to crops genetically modified to be resistant to insects and/or herbicides.

This report updates our previous estimates of the benefits associated with the adoption of genetically modified crop varieties. Updated impact estimates have been calculated for corn, cotton and soybeans. A discussion of potential impacts for potatoes is included. Each of these crops delivers a unique set of benefits to growers who adopt them. These benefits largely depend on pest control issues particular to each crop and whether other effective and affordable pest control options are available. Understanding the reasons why growers are adopting these varieties is critical in evaluating the their impact.

Insect resistant Bt corn varieties have allowed farmers to control the European Corn Borer, an insect pest that is difficult to control using conventional insecticides because it tunnels into the corn stalk soon after hatching, and is protected from the insecticides. Prior to the introduction of Bt corn, few growers were spraying for the corn borer. Instead, yield losses sometimes reached 300 million bushels of corn per year. With Bt corn, losses to the corn borer are eliminated. The primary benefit of Bt corn varieties has been increased yields. In 1999, it is estimated that 66 million bushels of corn were saved from the corn borer, or the equivalent of production on nearly 500,000 acres. Modest reductions in corn insecticide use have also been observed since the introduction of Bt corn.

Cotton growers have adopted genetically modified varieties faster than growers of any other crop. Both insect and herbicide resistant varieties have been adopted widely. Insect protected varieties of Bt cotton provide control of three of the most destructive insect pests in cotton: tobacco budworm, cotton bollworm and pink bollworm. Growers were managing these pests with several insecticide treatments per year. In some areas, the efficacy of these insecticides was diminished by the development of insecticide resistant insect populations. Bt cotton has allowed growers to reduce insecticide use and attain better control of these pests, which has resulted in increased yields. It is estimated that cotton growers reduced insecticide use by 2.7 million lbs and made 15 million fewer insecticide applications per year due to the introduction of Bt cotton. Cotton production has also increased, by 260 million lbs per year. Net revenues are estimated to have increased by $99 million in 1999.

Herbicide resistant cotton varieties provide growers with effective weed control programs that eliminate some of the problems associated with conventional programs. Until 1995, cotton growers did not have any broadleaf herbicides that could be used over a growing cotton crop without causing crop injury. Instead, herbicide treatments on small cotton required time consuming treatments using special equipment to treat weeds between the rows without contacting the crop. With the introduction of herbicide resistant cotton, growers can use broad spectrum herbicides over the growing crop with minimal crop injury. The introduction of herbicide resistant cotton varieties has led to a reduction in the number of herbicide applications made by cotton growers, by 19 million in 2000.

Insect and virus resistant potato varieties have been introduced that have great potential to decrease insecticide use in that crop. However, the recent introduction of a highly effective conventional insecticide and the refusal of processors to accept genetically modified potatoes have limited the adoption of these new varieties.

Finally, herbicide tolerant soybeans offer growers effective weed control with a simple, flexible program that has allowed many to reduce weed control costs. Prior to the introduction of herbicide tolerant soybeans, growers chose from many herbicides, often applying three or more active ingredients, some of which would cause damage to the growing soybean plants, or cause harm to corn crops that commonly follow soybeans. Herbicide tolerant soybeans allow growers to rely on one herbicide to control a broad spectrum of weeds without harming the current or rotation crops. The primary benefit of herbicide tolerant soybean varieties has been a reduction in weed control costs, of $216 million per year in 1999. Growers have also reduced the number of herbicide applications, by 19 million in 1999.

Introduction

U.S. farmers have adopted genetically modified crop varieties rapidly since their introduction in the mid-1990's. Genetically modified varieties of three major crops including corn, cotton and soybeans have been planted in the United States. (See Table 1.) A genetically modified potato variety has also been planted on limited acreage. Each of these crops delivers a unique set of benefits to growers who adopt them. These benefits largely depend on pest control issues particular to each crop and whether other effective and affordable pest control options are available. Understanding the reasons why growers are adopting these varieties is critical in evaluating the impact these technologies have had on US agriculture.

Previous estimates of aggregate benefits to U.S. farmers indicate higher yields, lower costs and ease of management. In addition, pesticide use has declined since the introduction of genetically modified varieties (Gianessi, et al. 1999, 2000; Carpenter, et al.). This report updates previous estimates of aggregate benefits resulting from farmers' adoption of genetically modified varieties for corn, cotton, potatoes and soybeans.

The aggregate impacts of the introduction of genetically modified crop varieties are summarized in tables 2-5. These tables present aggregate estimates of changes in net revenue, increases in production, decreases in pesticide use and decreases in pesticide acre treatments.

Table 1. Adoption of Genetically Modified Varieties in the U.S.

	1995	1996	1997	1998	1999	2000
	percent of U.S. acreage					
Bt corn		1	6	18	26	19
Bt cotton		12	18	23	32	39
Bt potatoes		1	2.5	<4	<4	2-3
RR cotton			4	21	37	54
RR soybeans		2	13	37	47	54
BXN cotton	0.1	0.1	1.2	5.8	7.8	7.2

Sources: Bt corn 1996-1999 from US EPA 2000; Bt corn 2000 from USDA NASS 2000a; cotton from USDA AMS; soybeans 1996-1999 from Marshall; soybeans 2000 from USDA NASS 2000a; potatoes 1996-1999 from US EPA 2000; potatoes 2000 from Owens

Table 2. Aggregate Impacts of Genetically Modified Varieties in the U.S.—Gain (Loss) in Net Revenues

	1998	**1999**
	millions	
Bt corn	($26)	($35)
Bt cotton	$92	$99
RR soybeans	$220	$216

Table 3. Aggregate Impacts of Genetically Modified Varieties in the U.S. — Increases in Production

		1998	**1999**
	units	millions	
Bt corn	bushels	60	66
Bt cotton	lbs	178	260

Table 4. Aggregate Impacts of Genetically Modified Varieties in the U.S.—Decreases in Pesticide Use

	1998	**1999**
	million lbs	
Bt cotton	2	2.7

Table 5. Aggregate Impacts of Genetically Modified Varieties in the U.S.—Decreases in Pesticide Acre Treatments[1]

	1998	1999
	millions	
Bt corn[2]	2	1
Bt cotton	9	15
HT cotton[3]	1.8	1
RR soybeans	16	19

[1] An application acre is the number of different active ingredients applied per acre times the number of repeat applications, and differs from the number of trips over the field, as one trip across the field to apply two active ingredients is treated as two applications, as is two treatments each containing a single ingredient.

[2] Bt corn insecticide reductions in number of acres treated

[3] HT cotton-herbicide tolerant cotton, including BXN and Roundup Ready varieties.

Corn

Bt field corn varieties were introduced for planting by U.S. farmers in 1996, offering built-in insect control. Adoption of Bt corn varieties was swift, rising to 26% of corn acres planted by 1999, the fourth year on the market. Adoption decreased to 19% in 2000, which is believed to be due largely to historically low target pest pressure in 1998 and 1999. Figure 1 shows adoption of Bt corn since its introduction in 1996.

Corn is the largest acreage crop grown in the U.S. Planted acreage totaled 80 million in 2000, which represents approximately one-quarter of the acreage planted to all crops in the U.S. Average corn yields totaled 134 bushels per acre in 1998 and 1999 (USDA NASS 2000a). Corn for grain production was estimated at 9 billion bushels in 1999 (USDA NASS 2000c) with a total value of production of $18 billion. This represents approximately 20% of the value of all crops grown in the U.S. (USDA NASS 2000d).

Figure 1. Bt Field Corn Adoption

Source: US EPA 2000; USDA NASS 2000a

All 48 coterminous states have corn acreage, and, in many states, corn is the single most important crop in terms of acreage and production value. Corn production is concentrated in the Midwest, where ten states account for 85% of U.S. acreage and production. Individually, the states of Illinois and Iowa account for over 10 million acres of corn each (USDA NASS 2000a).

The major use of corn produced in the U.S. is as a livestock and poultry feed, accounting for 60% of use, while food, seed and industrial uses (including sweeteners, fuel alcohols and starch) account for approximately 19% of use. Exports account for the remaining 21% of use (USDA NASS 2000b).

The U.S. is by far the largest corn producing country, growing 40% of the world's total production. China is the second largest producer, growing 21% of the world's total. Brazil, Mexico, France and Argentina are also major corn producing countries. The U.S. dominates the corn export market, accounting for 75% of the world's total exports. Major export markets for U.S.-grown corn are Japan (29%), Korea (12%), Mexico (10%) and Taiwan (8%). Western Europe accounts for less than 1% of U.S. corn exports (USDA NASS 2000b).

Bt corn varieties were genetically modified to express an insecticidal protein from the soil bacterium *Bacillus thuringiensis* (Bt). The Bt protein is selectively active against lepidopteran, or caterpillar insects, including the European Corn Borer (ECB), a major insect pest of field corn in the U.S. The ECB ingests the Bt protein when it starts to feed on the plant. The toxin binds to the gut membranes, which causes the ECB larvae to die.

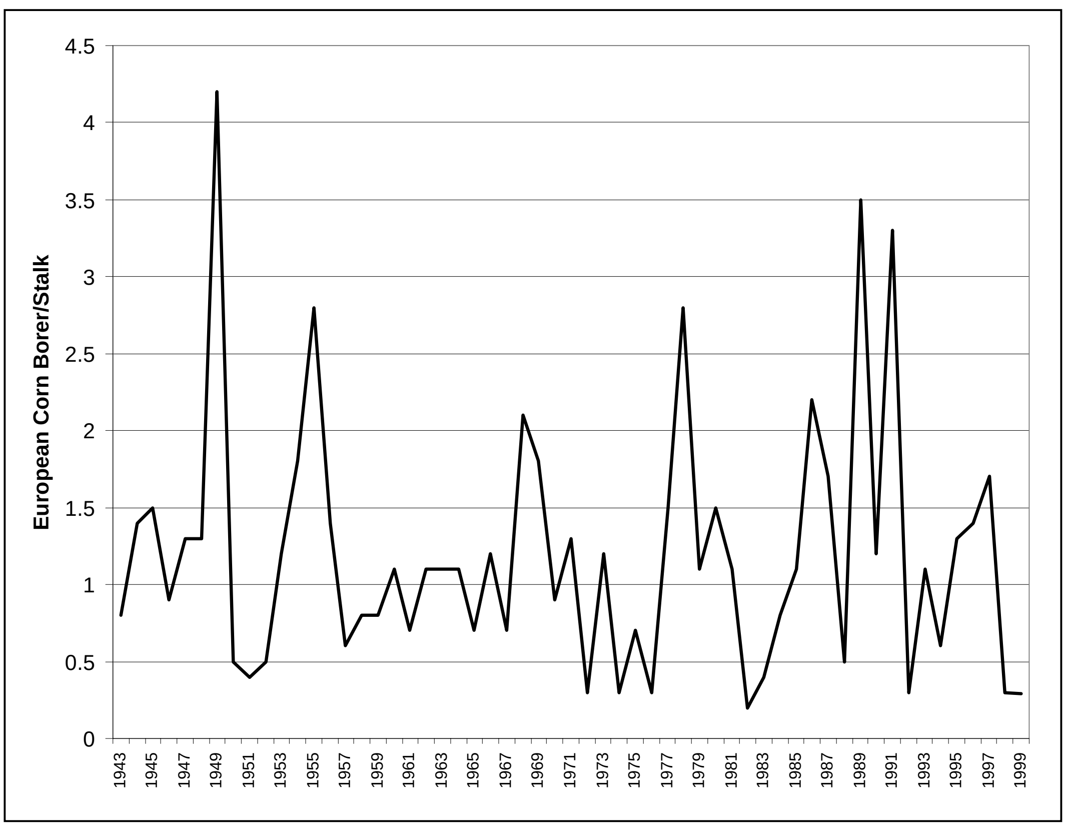
Due to the difficulty in scouting for this pest and the importance of timing insecticide application before the caterpillar bores into the corn stalk and is protected from insecticides, it is estimated that less than 5 percent of field corn acreage in the U.S. "Corn Belt" was being treated with insecticides for the ECB prior to the introduction of Bt corn varieties.

Researchers have sought alternative methods to control the corn borer, although none has proven effective on a wide scale. Traditional breeding efforts to select for natural resistance to the corn borer resulted in the development of varieties with intermediate levels of resistance that were widely used into the mid 1970s. However, acreage planted to these varieties decreased dramatically due to the introduction of much higher-yielding susceptible hybrids, which could produce higher yields than the resistant hybrids, even after sustaining high levels of damage from the corn borer. Another extensive research program was undertaken by the U.S. Department of Agriculture (USDA) to identify natural predators of the corn borer. The program resulted in the introduction of 24 species of parasites in U.S. corn production areas, of which only six became established. While these beneficial insects have provided control of the corn borer in some years in some areas, their impact has been limited.

Several different types of Bt field corn have been registered. The U.S. Environmental Protection Agency (EPA) has registered five unique Bt corn products: 176 (Novartis Seeds and Mycogen Seeds), Bt11 (Northrup King/Novartis Seeds), Mon 810 (Monsanto), DBT418 (Dekalb Genetics), and CBH 351 (Aventis, was AgrEvo). The Mon 810 and Bt11 events are used in production of YieldGard corn. Event 176 is sold as KnockOut by Novartis and Nature Gard by Mycogen. The DBT418 event is sold as BT-Xtra. The CBH351 event is sold as Starlink by Aventis. These events vary in the specific Bt protein that is produced, how much of the protein is produced, and where it is produced in the plant, thus affecting ECB control. The Starlink corn hybrid contains the Cry9C protein while all the other Bt hybrids contain the Cry1A(b) or Cry1A(c) protein. The Cry9C protein binds to a different site in the insect's gut. Cry9C is also toxic to black cutworms. The registration for Starlink varieties was voluntarily withdrawn by Aventis in October 2000. Starlink varieties had been planted on less than 1% of total U.S. corn acreage.

The impacts of Bt corn include increased yields and reduced pesticide use. However, the main advantage of Bt field corn has been increased yields, as only a small proportion of U.S. field corn acreage was sprayed for the ECB prior to the introduction of Bt varieties, as noted above.

Figure 2. European Corn Borer Densities in Illinois 1943-1999



Sources: Briggs, et al.; Gray, et al.; Monsanto; Steffey

Yield losses due to the corn borer vary from year to year with infestation levels, which are generally unpredictable from one year to the next. Figure 2 shows ECB infestation levels in Illinois for 1943 to 1999. Largely uncontrolled until the introduction of Bt corn varieties, the ECB has caused production losses that have ranged from 33 million bushels to over 300 million bushels per year (USDA APHIS). Bt corn varieties have been shown to provide a very high level of protection from the corn borer. Plants sustain only minute damage as the corn borer larvae attempt to feed.

The benefits that growers realize from planting Bt corn varieties depend on the level of infestation. In light infestation years the benefits may not be great, while in heavy infestation years growers will realize substantial yield increases. An average of available research results comparing yields from Bt and non-Bt corn fields indicates that growers experienced a yield advantage of approximately 12 bushels an acre in 1997, 4.2 bushels an acre in 1998 and 3.3 bushels an acre in 1999. The seed price premium, or technology fee, for Bt corn was approximately $10 an acre in 1997 and 1998 and $8 in 1999. Assuming corn prices of $2.43 a bushel in 1997, $1.95 a bushel in 1998 and $1.90 a bushel in 1999, the average income changes for Bt corn were an increase of $18 an acre in 1997, a decrease of $1.81 an acre in 1998 and a decrease of $1.73 an acre in 1999. It is expected that in 10 of the 13 years from 1986 to 1998, corn borer infestations in the Corn Belt were such that corn growers would have realized a gain from planting Bt corn (Monsanto). Table 6 shows aggregate cost and benefits estimates of Bt corn for 1997 through 1999.

The greatest impact of Bt corn varieties is the increase in production it provides through reduced yield losses due to the ECB. Table 7 shows the increase in production due to reduced yield losses due to Bt corn for 1997 through 1999. In 1999, growers were able to reduce their yield losses by 66 million bushels, the equivalent to production on nearly 500,000 acres of corn production that would otherwise have been destroyed by the corn borer.

Reductions in insecticide use are also expected due to the introduction of Bt corn varieties, though these reductions are anticipated to be modest due to low levels of insecticide use for ECB prior to the introduction of Bt corn. Attributing any observed changes in insecticide since 1995 to the introduction of Bt corn is necessarily problematic for several reasons. First, insecticides are typically used for control of several target pests. USDA pesticide use surveys do not report insecticide use by target pest, which means that isolating insecticide use targeted solely to the ECB is impossible. Second, insect populations by their nature are highly variable from year to year, which makes trends difficult to discern. Finally, the introduction of new products and development of resistance in insect populations to older products also drive shifts in insecticide use.

Five insecticides are currently recommended for control of ECB: Bt (foliar spray), chlorpyrifos, permethrin, lambdacyhalothrin, and methyl parathion. With the exception of foliarly applied Bt products, these insecticides are typically used for several target pests, including cutworms, rootworms, armyworms as well as the ECB.

Comparing 1995, the year before Bt corn varieties were introduced, to 1999, the use of these five insecticides declined. (See Table 8.) Of interest is the decline in use of four of the insecticides between 1995 and 1999: chlorpyrifos (-2%), permethrin (-1%), Bt (-1%), and methyl parathion (-2%). The decrease in the use of these insecticides may be due to the introduction of Bt corn varieties and the resulting reduced need for sprays targeted at the ECB. However, several other explanations are also possible to explain the change from 1995 to 1999. Lambdacyhalothrin was introduced in 1996, primarily for the treatment of cutworm in-season, which has likely displaced some of the use of the other insecticides, such as chlorpyrifos. Adult corn rootworm beetle populations have reportedly developed resistance to methyl parathion in some areas, which may account for part of the decline in its use. Finally, these reductions may be due to a decline in insecticide treatments targeted at pests other than the ECB. It is likely that all of these factors have affected use patterns of these insecticides.

The aggregate reduction of the percent acreage treated with the five insecticides is 6%. Assuming that 3% of the change is attributed to the introduction of lambdacyhalothrin, implies that a 3% decline occurred as a result of changes in the target pest complex, including ECB and other pests. For analytical purposes, it is assumed that one-half of the decline in the usage of the four insecticides (1.5%) was due to the introduction of Bt corn, implying over 1 million fewer acres sprayed for ECB.

Table 6. Aggregate Costs and Benefits of Bt Corn 1997-1999

	Costs	**Benefits**	**Net Gain (Loss)**
		(millions)	
1997	$47	$136	$89
1998	$144	$118	($26)
1999	$161	$126	($35)

Table 7. Aggregate Production Increases from Bt Corn 1997-1999

	Bushels/Acre	**Total Bushels (1,000)**
1997	11.7	55,832
1998	4.2	60,606
1999	3.3	66,436

Table 8. Corn Insecticides Used for European Corn Borer Control (Percent Acres Treated)

Active Ingredient	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
	percent of acres treated									
Chlorpyrifos	6.1	9	8	8	8	7	8	7	6	5
Lambdacyhalothrin							2	1	2	3
Methyl Parathion	0	2	1	2	2	3	2	4	1	1
Permethrin	1.4	2	2	2	3	4	4	5	1	3
Bt (foliar spray)	0	0	0		1	1	1	1	0	

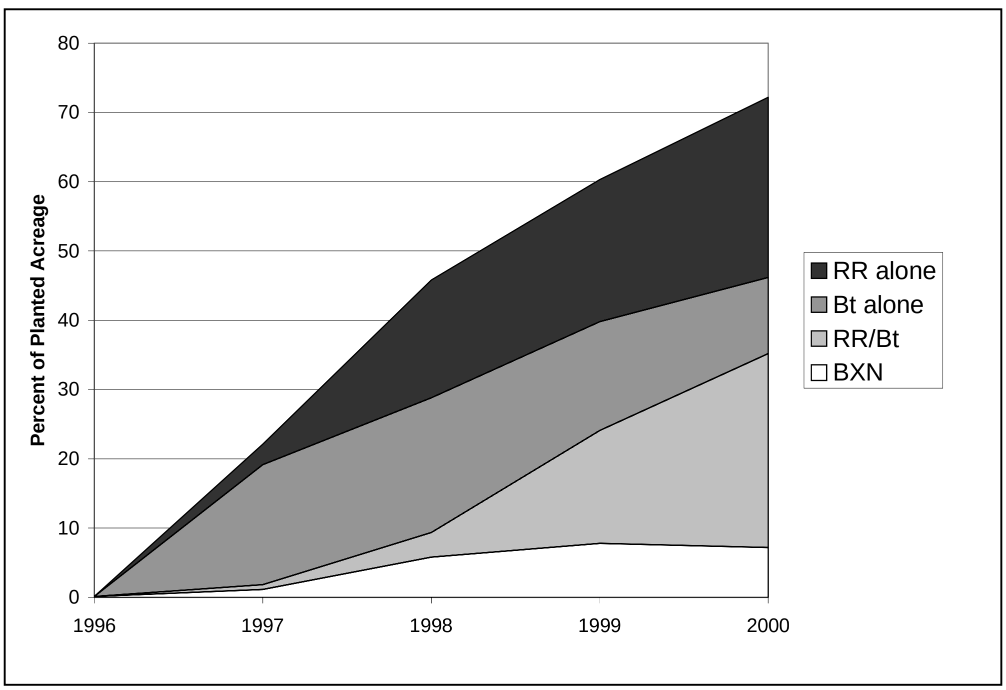
Source: USDA NASS

Cotton

In 2000, 72% of U.S. cotton acreage was planted to insect and/or herbicide resistant varieties: 39% *Bt*, 61% herbicide resistant and 28% "stacked" varieties with both insect and herbicide resistance (USDA AMS). Figure 3 and Table 9 show adoption of genetically modified cotton varieties since 1996.

Cotton is the fifth largest crop in the U.S., in terms of acreage in production, planted on over 15 million acres in 2000 (USDA NASS 2000a). In 1999, nearly 17 million bales of cotton were harvested, worth nearly $4 billion (USDA NASS 2000d). Cotton production is concentrated in the south and west. Texas is the largest cotton producing state, accounting for 40% of total U.S. acreage and 30% of total production in 2000. Georgia has recently expanded acreage to become the second largest cotton producing state, in terms of area in production, planting 9% of U.S. total acreage in 2000. California, North Carolina and Arizona each have nearly 1 million acres in cotton production (USDA NASS 2000a).

Figure 3. Transgenic Cotton Adoption



Note: RR-Roundup Ready, BXN-bromoxynil resistant
Source: USDA AMS

Table 9. Transgenic Cotton Adoption

	BXN	Bt	RR	RR/Bt	Total
	percent of planted acres				
1995	0.1				**0.1**
1996	0.1	12			**12**
1997	1.2	18	4	1	**22**
1998	5.8	23	21	4	**46**
1999	7.8	32	37	16	**60**
2000	7.2	39	54	28	**72**

Source: USDA AMS

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 offer 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 per year, 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.

Two surveys provide estimates of Bt cotton adoption. The USDA Agricultural Marketing Service estimates are based on informal surveys of cotton ginners, seed dealers, extension agents and others. In addition, the National Cotton Council sponsors an annual survey that provides estimates of adoption of Bt cotton varieties. The Cotton Council survey is coordinated by entomologists in each of the states, collecting information derived from surveys of county agents, extension specialists, private consultants and research entomologists. Tables 10 and 11 show estimates of adoption of Bt cotton from USDA AMS and the Cotton Council. Adoption estimates for 2000 are not yet available from the Cotton Council.

The adoption of *Bt* varieties was extremely rapid in some areas and has been slower in others. 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 over 60% of total acreage to *Bt* varieties in 1996 (Williams 1997; USDA AMS). In 2000, 65% of cotton acreage in Alabama was in *Bt* varieties (USDA AMS). Florida and Mississippi also adopted the technology on over 30% of cotton acreage in 1996. By 2000, four states had adoption rates of over 75%: Florida, Louisiana, Mississippi and Tennessee (USDA AMS). Figure 4 shows adoption of *Bt* varieties by state for 2000.

Two major cotton producing states have had very low adoption rates thus far, which skews the national adoption rate. Texas, which accounted for 40% of cotton acreage in 2000, has only adopted *Bt* cotton on a small scale, at only 10% in 2000. Adoption has been hindered by the lack of stripper varieties appropriate for growing conditions in Texas. California also has low adoption rates, which is at least partially due to a unique law in that state that controls which varieties may be planted. 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.

Table 10. USDA AMS Bt Cotton Adoption Estimates

	1996	**1997**	**1998**	**1999**	**2000**
	percent of planted acres				
Alabama	65	80	61	75	65
Arizona	11	64	57	56	57
Arkansas	15	14	14	22	60
California	0	2	5	8	6
Florida	42	79	80	66	75
Georgia	23	34	47	51	48
Louisiana	21	32	71	67	81
Mississippi	37	45	60	66	75
Missouri	0	0	0	1	5
New Mexico	9	13	38	28	36
North Carolina	3	2	4	37	41
Oklahoma	2	7	2	47	55
South Carolina	16	27	17	84	71
Tennessee	0	6	7	59	76
Texas	1	4	7	9	10
Virginia	0	3	1	16	41
US	**12**	**18**	**23**	**32**	**39**

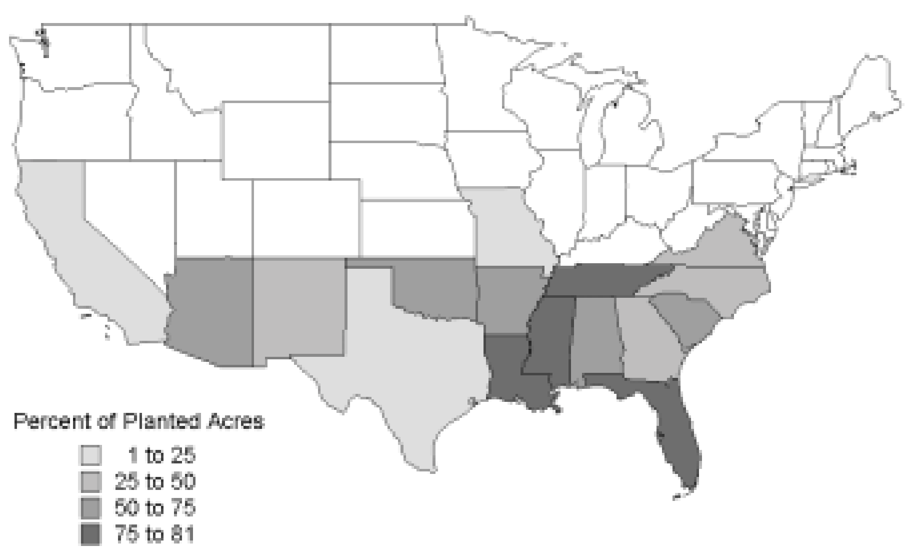
Source: USDA AMS

Table 11. Cotton Council Bt Cotton Adoption Estimates

	1996	1997	1998	1999
	percent of planted acres			
Alabama	77	68	63	66
Arizona	21	61	71	63
Arkansas	14	13	12	16
California	0	0	1	3
Florida	43	60	50	56
Georgia	30	38	44	58
Louisiana	15	38	60	61
Mississippi	35	43	58	67
Missouri	0	1	1	2
New Mexico	1	6	35	23
North Carolina	6	3	12	20
Oklahoma	6	8	8	21
South Carolina	14	31	39	81
Tennessee	1	3	19	68
Texas	2	5	5	8
Virginia	0	0	3	7
US	**13**	**17**	**21**	**29**

Source: Williams

Figure 4. Bt Cotton Adoption 2000



Source: USDA AMS

The impact of the adoption of Bt cotton varieties has been a reduction in yield losses due to Bt-target pests, reductions in insecticide use, and cost savings. 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 varied between 2 and 7% from 1996 to 1999. The number of insecticide applications per year was reduced from 10 to between 0 and 2 (Williams). Yield losses due to Bt target pests have declined in 12 of 16 reporting states. Table 12 shows percent yield losses due to cotton bollworm, tobacco budworm and pink bollworm by state for 1985 to 1999.

The major impact of the adoption of *Bt* varieties is a reduction in insecticide use. There are two sources of cotton insecticide use data available. The first is the Cotton Council survey, which estimates insecticide use by target pest. The number of insecticide treatments for cotton bollworm, tobacco budworm and pink bollworm decreased in 1999 compared to 1995 in 12 of 16 reporting states. Table 13 shows the number of insecticide applications directed toward cotton bollworm, tobacco budworm and pink bollworm by state from 1986 to 1999.

As part of the Cotton Council survey, three states report insecticide use separately for Bt acreage and conventional acreage. (See Table 14.) In all three states, the number of insecticide treatments directed at Bt target pests was lower on Bt acreage. However, treatments for other insects (except for boll weevil) were higher on Bt acreage. This is believed to be due to the emerging importance of pests that were previously considered secondary pests, which were previously controlled with treatments at Bt target pests. However, the reduction in treatments for Bt targets is larger than the increased number of treatments towards these secondary pests in all three instances. Finally, in Louisiana and Tennessee, the number of treatments for boll weevil is higher on Bt acreage than on conventional acreage. This is likely due to higher adoption rates for Bt cotton in boll weevil eradication areas.

USDA pesticide use data record insecticide use by active ingredient without indication of target pest. Comparing USDA pesticide use data for 6 states for 1995 to 1998 and 1999 shows a dramatic reduction in the use of insecticides used to control cotton bollworm, tobacco budworm and pink bollworm. Table 15 shows reductions in insecticide use for those insecticides that are recommended for cotton bollworm, tobacco budworm and pink bollworm control. This difference in use was adjusted to account for reduction in planted acreage since 1995. The use of cotton insecticides for Bt target pests declined by over 2 million pounds between 1995, the year before Bt varieties were introduced, and 1998, and by 2.7 million pounds by 1999. These reductions account for 10% and 14% of all insecticides used in those six states in 1995. The number of insecticide applications has also declined, by 8.7 million applications in 1998 and by 15 million applications in 1999, or 13% and 22% of the total number of insecticide applications in those states in 1995.

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 5 studies in 7 states including 91 comparisons in 1999, comparing *Bt* to conventional varieties was $20.81/acre, taking into account the technology fee. (See Table 16.) On average, per acre insect control costs were $14.28 higher. This increased cost was outweighed by a yield increase of 9%, or 55 lbs/acre. These yield and revenue impacts, if realized over all 4.67 million acres of *Bt* cotton in 1999, would result in a $99 million increase in revenues and 260 million lbs increased cotton production.

Herbicide Resistant Cotton

In 1995, BXN cotton was introduced. BXN cotton is tolerant to bromoxynil (Buctril), 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 (Roundup).

Nearly all U.S. cotton acreage is currently treated with herbicides. In 1998, 95% of U.S. cotton acreage was treated with herbicides (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 1997). 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 without the potential to cause crop injury. Instead, growers would use directed, post-emergence applications of nonselective herbicides, using specialized equipment to avoid herbicide contact with the growing crop plants, and cultivation. Directed, post-emergence treatments require weeds to be shorter than the cotton crop. 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 1999, its use had dropped back to 14% (USDA NASS), likely due to competition with weed control programs using newly introduced herbicide tolerant cotton varieties.

Table 12. Yield Losses Due to Tobacco Budworm, Cotton Bollworm and Pink Bollworm

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	percent														
Alabama	2.6	4.5	4.5	2.6	3.4	1.4	1.7	2.5	6.8	6.1	29.1	3.1	3.2	4.7	2.0
Arizona	3.6	2.9	2.3	1.4	1.5	4.6	1.1	0.7	0.1	3.9	1.2	2.8	2.7	0.0	1.0
Arkansas	1.8	1.8	1.1	1.4	1.0	1.3	1.5	2.6	1.5	1.8	3.6	3.1	2.7	4.7	1.3
California	0.8	0.0	0.0	1.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Florida	4.3	5.5	7.2	4.4	5.5	9.1	4.0	3.0	3.0	3.7	3.9	3.3	4.3	2.1	0.7
Georgia	3.6	4.1	2.1	2.7	4.7	5.0	1.0	1.8	1.9	1.9	2.8	1.9	2.5	2.8	0.8
Louisiana	4.0	5.3	2.7	2.3	5.8	4.0	3.5	7.5	3.6	2.9	3.2	2.3	1.9	1.5	0.8
Mississippi	1.3	4.9	4.6	4.9	4.6	4.5	0.6	3.9	3.9	4.1	8.0	1.9	2.4	4.2	2.5
Missouri	1.0	0.6	1.9	7.5	0.0	1.1	1.6	1.7	0.9	0.5	1.4	1.3	1.3	6.1	0.7
New Mexico	4.5	3.9	0.8	2.4	2.5	5.0	3.4	1.6	3.0	1.6	3.3	10.6	8.6	6.1	3.7
North Carolina	8.5	2.5	0.9	5.2	8.6	3.6	12.6	4.3	2.3	6.4	3.7	5.2	5.3	4.4	4.1
Oklahoma	5.0	1.8	1.9	1.3	0.5	1.2	1.6	3.3	3.1	1.7	2.5	3.3	3.0	4.0	5.0
South Carolina	4.3	3.2	2.1	4.6	2.6	2.4	1.9	2.8	3.4	3.4	4.7	5.0	4.7	3.5	1.9
Tennessee	3.0	2.0	2.1	1.6	0.8	0.3	1.0	1.0	6.7	0.5	10.8	0.8	1.0	5.9	1.6
Texas	3.8	2.3	1.9	0.9	1.5	1.1	1.8	1.4	0.5	0.8	1.0	3.0	1.7	1.3	0.4
Virginia	15.0	10.0	2.4	3.4	4.7	12.5	4.0	0.2	0.0	0.5	1.0	2.0	0.3	0.0	0.3

Source: Williams

Table 13. Insecticide Treatments for Tobacco Budworm, Cotton Bollworm and Pink Bollworm

	1986	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
	number of applications per year													
Alabama	5.2	4.9	2.0	3.7	2.5	2.9	2.9	4.8	4.4	6.7	0.1	0.5	1.4	0.4
Arizona	2.2	6.3	2.9	3.9	7.4	3.2	1.1	0.1	2.9	2.9	2.0	1.1	0.1	0.4
Arkansas	2.9	1.3	2.9	2.6	2.4	3.3	3.7	3.6	3.0	4.6	2.3	1.6	3.1	0.5
California	0.1	0.0	0.6	0.2	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Florida	9.0	7.1	5.6	8.4	7.2	5.0	5.0	5.3	5.3	5.7	1.1	1.0	2.0	0.5
Georgia	7.3	6.2	4.4	4.3	5.0	4.9	3.4	2.7	4.3	3.4	1.7	2.5	1.5	0.6
Louisiana	5.5	4.3	3.7	5.8	5.0	3.5	5.8	4.7	4.8	4.7	3.9	3.2	3.5	1.2
Mississippi	4.6	4.7	3.7	4.8	3.4	1.5	5.1	4.3	4.1	5.7	2.2	2.5	2.5	1.3
Missouri	0.3	0.6	1.5	0.0	0.1	0.3	0.3	0.9	0.8	1.3	0.1	0.7	1.6	0.9
New Mexico	1.1	0.1	0.4	0.6	1.1	0.8	0.3	0.3	0.7	0.8	1.1	0.7	2.0	1.1
North Carolina	3.5	2.7	2.6	2.9	2.8	3.1	3.0	2.5	3.6	2.6	3.1	2.0	3.0	1.9
Oklahoma	1.8	1.1	1.3	0.8	0.9	1.3	1.1	2.3	0.7	1.8	1.7	1.9	1.5	0.7
South Carolina	3.1	2.8	3.7	3.5	3.8	3.8	3.7	4.9	4.4	4.7	4.2	3.3	3.4	1.1
Tennessee	0.4	0.5	0.3	0.4	0.3	0.6	0.1	2.0	0.3	2.9	0.2	0.3	2.7	0.6
Texas	0.8	1.2	0.8	0.7	0.7	1.1	0.7	0.4	0.7	0.5	0.7	0.6	0.6	0.1
Virginia	2.0	1.0	1.4	0.8	1.5	2.5	0.2	1.0	1.7	1.5	1.0	1.2	2.2	1.8

Source: Williams

Table 14. Cotton Insecticide Applications in Bt and Conventional Varieties 1999

	Arizona		Louisiana		Tennessee	
Target Pest	**Bt**	**Conv.**	**Bt**	**Conv.**	**Bt**	**Conv**
Cotton Bollworm, Tobacco Budworm and Pink Bollworm	0.0	1.1	0.8	1.8	0.3	1.2
Boll Weevil	0.0	0.0	3.1	2.7	4.5	3.9
Other Insects	1.6	1.4	3.4	3.3	2.1	1.5
Total	1.6	2.5	7.3	7.8	6.8	6.6

Source: Williams 2000

Table 15. Reductions in Cotton Bollworm/Tobacco Budworm/Pink Bollworm Insecticide Use After Introduction of Bt Varieties (AR, AZ, CA, LA, MS, TX)

	Reduction from 1995 to 1998		**Reduction from 1995 to 1999**	
	Pounds (1,000)	**Applications (1,000)**	**Pounds (1,000)**	**Applications (1,000)**
Amitraz	66	347	73	408
Cyfluthrin	23	824	72	2,115
Cypermethrin	62	1,696	109	2,550
Deltamethrin	-15	-566	-1	-88
Esfenvalerate	34	885	40	1,039
Lambdacyhalothrin	35	1,154	85	2,870
Methomyl	328	1,238	404	1,457
Profenofos	955	1,804	1,114	2,091
Spinosad	-31	-481	-19	-288
Thiodicarb	568	1,888	842	2,574
Tralomethrin	22	988	26	1,165
Zeta-cypermethrin	-40	-1,037	-31	-751
Total	**2,008**	**8,738**	**2,715**	**15,142**

Source: USDA NASS

Table 16. 1999 Comparisons of Bt and Conventional Cotton Performance

Study	State	# of Comparisons	Difference in Insect Control Costs[1]	Difference in Lint Yield[2]	Difference in Gross Return[1]	Difference in Net Return[1]
			$/acre	%	$/acre	$/acre
Cooke, et al.	MS	13	11.19	2	18.67	1.23
Karner, et al.	OK	14	16.47	19	77.50	40.06
Reed, et al.	MS	5	14.66	12	39.52	24.86
Seward, et al.	TN	8	19.00	3	10.20	(9.00)
Mullins	AR, AL, MS, LA	29	6.46	7	37.20	31.12
	West TX	22	17.89	10	53.89	36.61
Average			**14.28**	**9**	**39.50**	**20.81**

[1] Differences are values for Bt varieties minus values for conventional varieties.

[2] Percent difference of Bt yields over conventional yields.

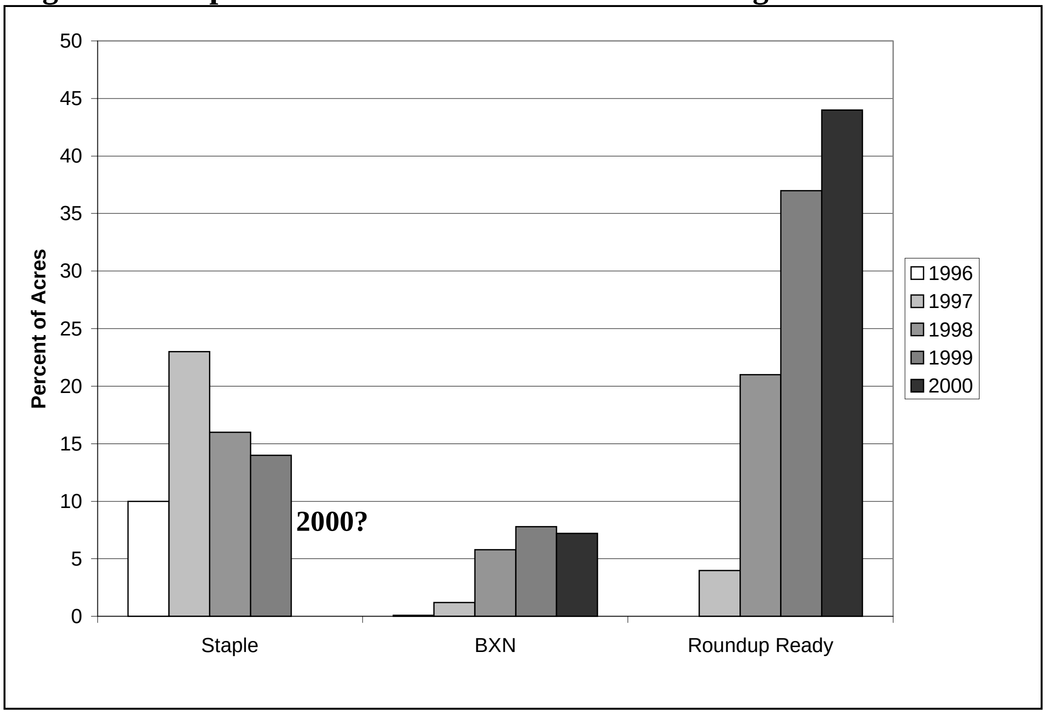
The adoption of BXN and Roundup Ready varieties has been driven largely by the ease and convenience of avoiding early directed post-emergence herbicide applications, as well as having new tools to control particular weed problems. Along with the introduction of Staple, growers now have three new post-emergence herbicides for broadleaf weed control. This is especially valuable in areas where weeds have become resistant to other commonly used herbicides. Figure 5 shows adoption of these three new herbicide technologies since 1996.

BXN cotton varieties were first planted in 1995, when EPA approved the use of bromoxynil for cotton. On May 18, 1995, EPA established time-limited tolerances for residues of bromoxynil on cottonseed, which allowed the use of bromoxynil over BXN cotton varieties. The accompanying registration allowed 200,000 acres of cotton to be treated with bromoxynil. On June 18, 1997, EPA renewed the time-limited tolerances, with an accompanying registration that increased the allowable treated acreage to 400,000 acres. On May 13, 1998, EPA established permanent tolerances for bromoxynil in cotton, with an accompanying registration allowing 1.3 million cotton acres to be treated with bromoxynil (US EPA 1998).

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.

Adoption of BXN cotton varieties was very low until 1998. By 1998, adoption was almost 6%, rising to nearly 8% in 1999 and falling slightly to just over 7% in 2000. With current limitations on the total acreage that may be treated with bromoxynil, adoption can not increase substantially from current levels. The relatively small national adoption numbers hide what has been substantial adoption in some areas. In 1997, 7% of North Carolina and 4% of Tennessee acreage was planted to BXN varieties. 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. Missouri currently has the highest adoption rate for BXN varieties at nearly 40% of planted acres (USDA AMS). Table 17 shows adoption rates of BXN varieties by state since 1995. Figure 6 shows adoption by state for 2000.

Figure 5. Adoption of Cotton Weed Control Technologies



Sources: USDA NASS; USDA AMS

Roundup Ready varieties, which are tolerant to the application of glyphosate (Roundup), became available in 1997. Roundup is a highly effective broad spectrum herbicide that controls both grasses and broadleaf weeds. Roundup Ready varieties are not perfectly tolerant to treatment with Roundup, however. Over the top treatment with Roundup may be made only until the 4-leaf growth stage, after which time, directed post-emergence treatments must be made.

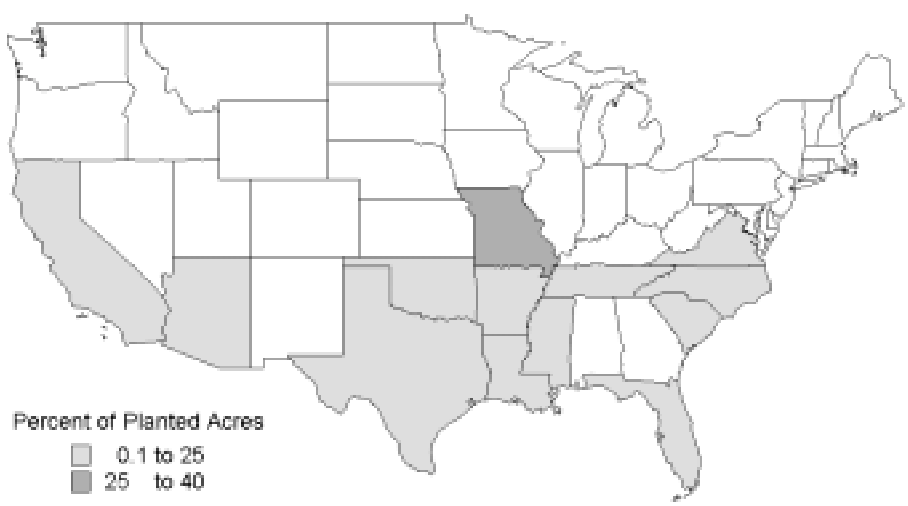
Since 1997, adoption of the technology has been rapid, growing from 4% in 1997 to 54% in 2000. Some areas have adopted the technology more rapidly than others. South Carolina planted 94% of its cotton acreage to Roundup Ready varieties in 1999 which is believed to be due to the effectiveness of Roundup on sicklepod, and DNA-resistant palmer amaranth (Murdock). Florida and Tennessee have also adopted at rates over 75% of planted acreage (USDA AMS). Table 18 shows adoption rates of Roundup Ready varieties by state since 1997. Figure 7 shows Roundup Ready cotton adoption by state for 2000.

Table 17. BXN Cotton Adoption

	1995	1996	1997	1998	1999	2000
	percent of planted acres					
Alabama						
Arizona		0.1	0.3	1.0	1.9	1.7
Arkansas	0.3	0.5	2.0	27.8	41.3	21.9
California					3.0	8.7
Florida					0.7	0.3
Georgia		0.2	0.7	2.5	2.3	0.8
Louisiana	0.2	0.3	0.6	8.0	8.7	3.4
Mississippi	0.3	0.2	3.1	6.2	15.0	11.0
Missouri	0.2	0.1	0.7	11.1	29.9	39.5
North Carolina	0.1	0.1	7.1	4.3	13.4	13.1
Oklahoma				1.6	0.7	2.9
South Carolina	0.2	0.2	1.1	0.2	1.2	0.4
Tennessee			3.7	39.6	10.3	7.3
Texas		0.1	0.2	0.4	1.1	1.8
Virginia				3.4	11.2	16.4
US	**0.1**	**0.1**	**1.2**	**5.8**	**7.8**	**7.2**

Source: USDA AMS

Figure 6. BXN Cotton Adoption 2000



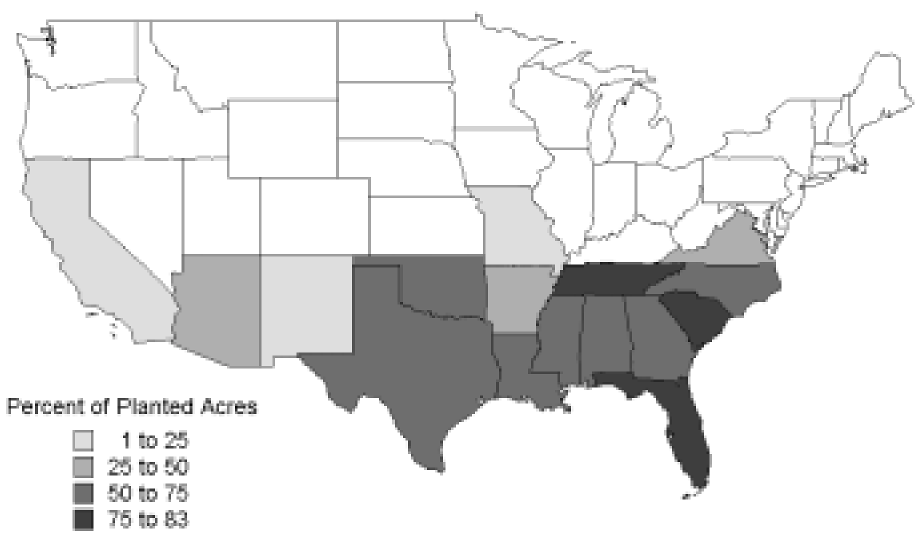
Source: USDA AMS

Table 18. Roundup Ready Cotton Adoption

	1997	1998	1999	2000
	percent of planted acres			
Alabama	1	13	40	60
Arizona	2	11	12	25
Arkansas	5	3	8	42
California			2	21
Florida		7	54	83
Georgia	2	35	55	66
Louisiana	1	3	12	54
Mississippi	11	10	27	53
Missouri		2	4	22
New Mexico	1	2	2	4
North Carolina	10	32	58	65
Oklahoma	2	22	57	68
South Carolina	4	45	94	76
Tennessee	11	18	57	81
Texas	2	27	41	55
Virginia	3	19	39	49
US	4	21	37	54

Source: USDA AMS

Figure 7. Roundup Ready Cotton Adoption 2000



Source: USDA AMS

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 (Coble). In field trials of conventional programs with and without Staple compared to BXN and Roundup Ready programs, relative yields and net returns varied. Table 19 shows average relative yields compared to a conventional program from trials conducted in six states in 1997 and 1998. Table 20 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 has caused shifts in pesticide use patterns and reduced herbicide use in cotton production. Use of many of the most commonly used herbicides, such as trifluralin, fluometuron, and MSMA, has declined since 1994. Table 21 shows the extent of use of cotton herbicides by active ingredient in 1994, the year before BXN cotton varieties were introduced, to 1999. Glyphosate use increased from use on 8% of planted acres in 1994 to use on 36% in 1999 (USDA NASS).

Herbicide use in cotton is expected to decline with the adoption of herbicide tolerant varieties. Application rates for conventional programs vary between 5.5 and 9 lbs./acre, 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. USDA data show that average application rates decreased from 1.7 lbs/acre in 1997 to 1.63 lbs/acre in 1999. There has been a general decline in average cotton herbicide application rates since 1994. (See Table 22.) The total amount of herbicide applied to cotton acreage has also declined since 1995. (See Figure 8.) Further, the number of applications made to cotton acreage has declined by 1.8 million applications in 1998 and 1.3 million applications in 1999 compared to 1994. (See Figure 9 and Table 23.)

Table 19. 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%

Sources: Brecke, Bridges, Hayes, Miller, Snipes, Wilcut

Table 20. Comparison of Net Returns for Tennessee and Lousiana 1998 ($/acre)

	Tennessee		Louisiana	
Program	**Net Return ($/acre)**	**Rank**	**Net Return ($/acre)**	**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

Sources: Hayes, Miller

Table 21. Use of Individual Cotton Herbicide Active Ingredients 1994 and 1999

	1994	1999
	percent of acres treated	
2,4-D		1
Bromoxynil		7
Clethodim		2
Clomazone	12	3
Cyanazine	18	15
Diuron	11	24
DSMA	5	2
Fluazifop	4	1
Fluometuron	30	27
Glyphosate	8	36
Lactofen	3	
Metolachlor	4	5
MSMA	22	18
Norflurazon	13	5
Pendimethalin	18	24
Prometryn	26	14
Pyrithiobac		14
Trifluralin	61	52

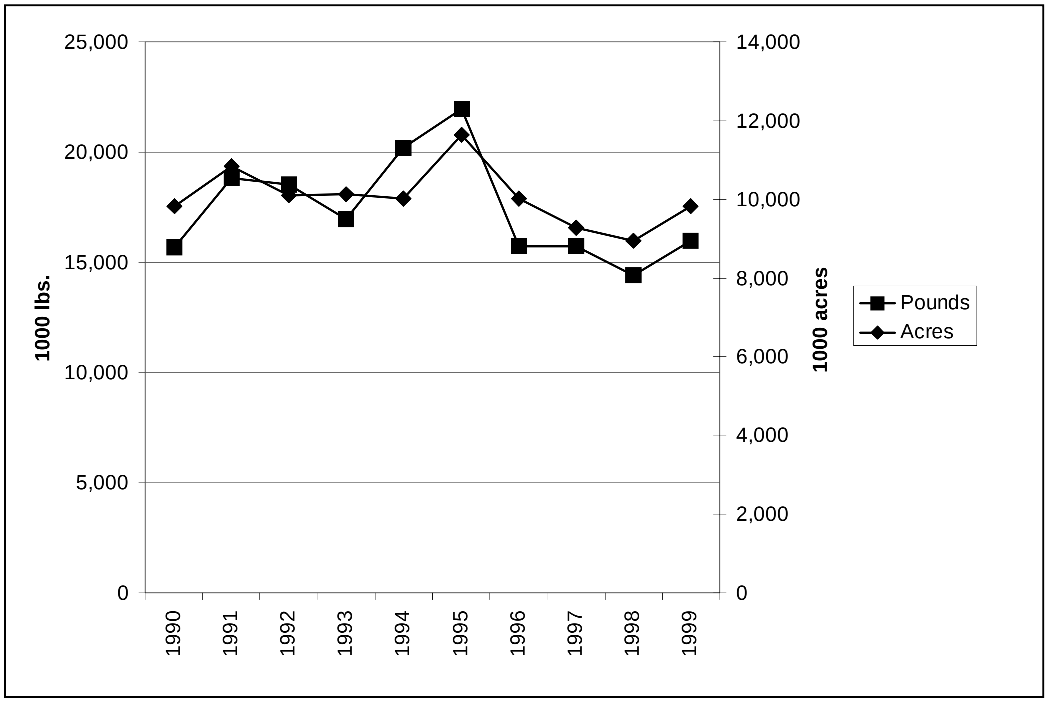
Source: USDA NASS

Table 22. Cotton Herbicide Application Rates 1994 to 1999

	lbs/acre	applications/acre
1994	2.02	2.96
1995	1.89	2.91
1996	1.57	2.53
1997	1.7	2.84
1998	1.61	2.76
1999	1.63	2.82

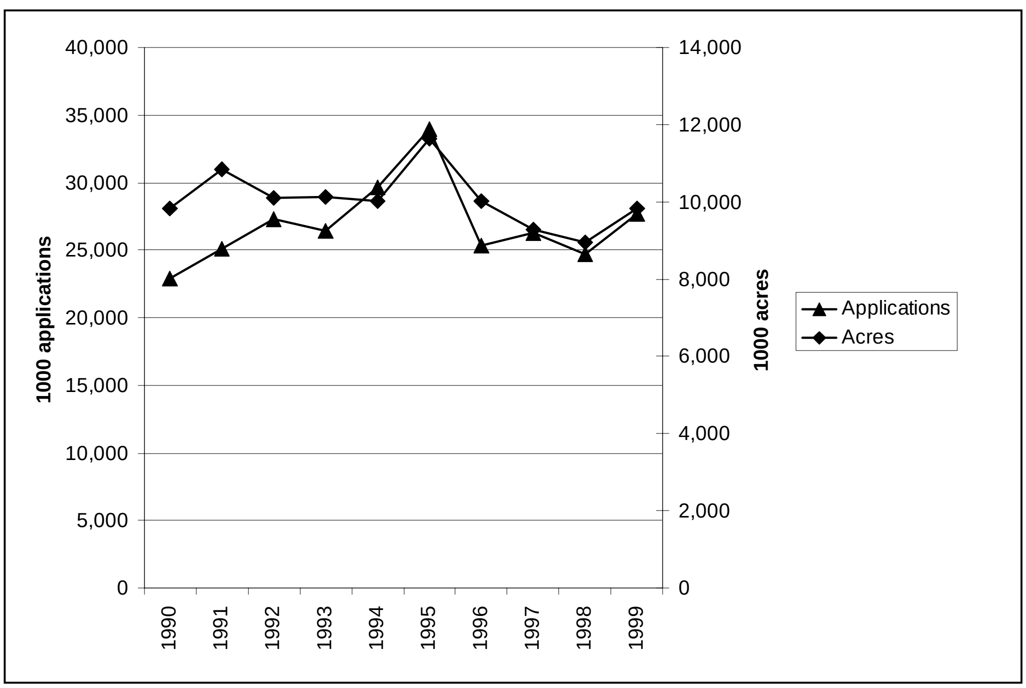
Source: USDA NASS

Figure 8. Herbicide Use in Cotton 1990-99 (AR, AZ, CA, LA, MS, TX)



Source: USDA NASS

Figure 9. Cotton Herbicide Applications 1990-99 (AR, AZ, CA, LA, MS, TX)



Source: USDA NASS

Table 23. Reductions in Cotton Herbicide Use Since Introduction of Herbicide Tolerant Varieties

	1994 to 1998	1994 to 1999
	1,000	
Pounds	3,643	3,825
Applications	1,775	1,316

Much of the decline in total pounds of herbicides used in cotton since 1995 is likely due to the adoption of Staple and is probably not attributable to the introduction of herbicide tolerant varieties. Staple is used at a very low average rate, 0.05 lbs/acre, compared to other herbicides that are used at 0.09 lbs/acre to 1.18 lbs/acre (USDA NASS 2000). However, the decline in the number of applications is more likely due to the introduction of herbicide tolerant varieties and the associated use of broad spectrum herbicides, such as Roundup, which reduce the number of herbicides needed for effective weed control. Reductions in cotton herbicide use since the introduction of herbicide tolerant varieties are shown in Table 23. Reductions have been adjusted to account for the decline in acreage in recent years.

The impact of the introduction of genetically modified cotton varieties has been a reduction in the total amount of insecticides used, reductions in the numbers of insecticide and herbicide applications, increased yields and increased returns to farmers. The use of insecticides declined by 2.7 million pounds by 1999, while the number of insecticide applications has declined by over 15 million applications. Herbicide use has also declined, although the decline in the total amount of herbicides applied may not all be attributable to the introduction of herbicide tolerant varieties. The number of herbicide applications has declined by over 1 million applications. Production increased by 260 million lbs per year. Returns have increased $99 million.

Potatoes

Bt potato varieties were introduced in 1996, and have been adopted on a very limited basis. One percent of the total U.S. potato acreage was planted to Bt potato varieties in 1996. By 2000, adoption was between 2 and 3 %. (See Table 1.) Three types of Bt potatoes are available: NewLeaf Bt potato, introduced in 1996; NewLeafPlus Bt potato with resistance to the potato leafroll virus, introduced in 1999; and NewLeafY Bt potato with resistance to potato virus Y, also introduced in 1999. Adoption figures reflect combined adoption of the three types of Bt potatoes. The low adoption rates are due to a combination of factors. Early adoption of Bt potato varieties, prior to the introduction of stacked varieties, was hindered by the continuing need by potato growers to control other insect pests in addition to the Colorado Potato Beetle, which limited potential insect control cost savings. More recently, rejection by processors in response to McDonald's and other buyers' refusal to buy genetically modified potato products has limited adoption (Kilman). Finally, the introduction of a very effective conventional insecticide just prior to the introduction of Bt potatoes provided growers with an attractive alternative to Bt varieties.

Potatoes are grown on 1.4 million acres in the U.S., producing over 45 billion pounds of potatoes annually (USDA NASS 2000b). Total crop value was $2.8 billion in 1999 (USDA NASS 2000d). Fifty-three percent of annual U.S. potato production is located in the Pacific Northwest states of Idaho, Washington and Oregon. Other major potato producing states include Wisconsin, Colorado, North Dakota, Minnesota, Maine, California and Michigan (USDA NASS 2000c).

The majority of potatoes are processed into food products or ingredients. Sixty percent of total production is processed, of which 50% is made into frozen french fries, the rest is either dehydrated (19%), made into chips or shoestring potatoes (17%), other frozen products (9%), or other end products. Twenty-six percent of total potato production is grown for table stock. The remaining production is used either for seed (6%), is not marketed due to shrinkage or loss (7%) or is used for livestock feed or household use (USDA NASS 2000b).

Potatoes are annuals produced from certified potato seed pieces taken from the previous year's crop. Potatoes and seed potatoes are produced in the same manner, except that seed potatoes receive more intensive pest management to ensure disease-free planting stock (Schreiber, et al.).

The target insect pest of all Bt potato varieties is the Colorado Potato Beetle (CPB), which is more of a problem in the East than in Northwest production areas. CPB consumes plant foliage, which leads to reduced photosynthesis and consequent yield reductions. The CPB is the major defoliating insect pest of potatoes in the U.S. If uncontrolled, the CPB can completely defoliate all potato plants in a field by mid-season.

Few insects have shown the potential to develop resistance to as broad a range of insecticides as the CPB. Eastern potato growers have found it necessary to change insecticides every few years as the CPB developed resistance to every insecticide used extensively against it (Casagrande). In the face of declining efficacy of conventional insecticide treatments, potato growers had resorted to other methods to control the CPB, such as using propane burners or constructing plastic-lined trenches in the borders around fields. Biological control of the CPB has been pursued using a fungal pathogen toxic to the beetle, but the success of this program was limited because fungicides used to control blights also killed the fungus. The introduction of predatory stink bugs has also been attempted, but difficulty attaining high enough populations of the stink bugs to provide control of the beetle limits the value of this practice (Ferro, et al.).

Aphids are another major insect pest of potatoes. Aphid infestation may reduce potato yields directly through feeding damage to the foliage, but causes more damage indirectly by transmission of viruses. The potato leaf roll virus (PLRV) is transmitted mainly by the green peach aphid and is prevalent in the Pacific Northwest. Aphids spread the virus when feeding, infecting expanding areas around the primary inoculum source as the aphids move from plant to plant. These expanding areas may engulf entire fields within a few weeks if the aphid populations are not controlled. Incidence of PLRV infection routinely approaches 100% in potato crops in the Northwest when insecticides are not used (Thomas, et al.). PLRV infection symptoms include leaf rolling, stunted plants, and discoloration of leaves, that become stiff, dry and leathery. PLRV infections reduce potato plant vigor and result in high yield losses (Hooker). PLRV also infects developing tubers, causing net necrosis, or stem end browning. Symptoms may not be evident at harvest, but may develop during storage. Losses in marketable yield can reach as high as 50-80% (Benttari).

The Russet Burbank potato variety is the dominant variety in the Northwest. The Russet Burbank is susceptible to potato leaf roll virus and the associated tuber net necrosis. The disease can limit production because the discolored tubers are not suitable for processing or table stock. The green peach aphid is the only important vector of the virus in the West and, because of this, is the key insect pest of Russet Burbank potato crops (Bishop, et al.).

Another major aphid-borne virus of potato is potato virus Y (PVY). PVY is transmitted mainly by the green peach aphid and the buckthorn aphid. Unlike PLRV, PVY is also transmittable mechanically by leaf contact and injury, although aphid transmission is the most important means of spread in the field. Diseases caused by PVY are severe mosaic, leaf-drop streak, and potato veinbanding mosaic. Reported losses range from 10 to 80% (Rowe). PVY does not cause price discounts due to damaged tubers as PLRV coes, but is considered one of the most damaging potato viruses in causing yield depression (Hooker). Control of PVY is especially important in the production of certified seed potatoes in Maine and Canada (Owens).

A new insecticide, imidacloprid, was commercialized for use in potatoes for the 1995 season and provides highly effective control of the Colorado potato beetle, aphids and other foliar-feeding insects. Imidacloprid is applied in furrow when the potato seed is planted, is taken up through the plant, persists in the plant and controls insects that feed on the plant. Following the introduction of imidacloprid in 1995, Eastern potato growers stopped using all of the cultural methods of beetle control (burners, trenches), except for crop rotation. USDA pesticide use data show use of imidacloprid on 34% of acres in 1999. (See Table 24.) Midwest and Eastern states treat a higher proportion of potato acreage with imidacloprid than in northwest production areas. Ninety-three percent of Michigan potato acreage was treated with imidacloprid in 1999; 90% in Maine; and 81% in Pennsylvania.

The cost of an imidacloprid application at planting is $60 per acre (Michigan Potato Industry Commission). Imidacloprid has dramatically reduced populations of CPB in Eastern states. The reduction in CPB populations has been estimated to be as high as 99.9% in some locations. Thus, CPB populations throughout the Midwestern and Eastern potato growing regions of the U.S. have declined dramatically (Whalon, et al.). Yield losses due to CPB have become minimal to nonexistent (Michigan Potato Industry Commission).

With the exception of propargite, all insecticides commonly used in the Pacific Northwest are primarily to control CPB and aphids (Pacific Northwest Insect Control Handbook). In eastern production areas, all commonly used insecticides are directed primarily at CPB, except carbaryl, diazinon, dimethoate and methyl parathion (Cornell Cooperative Extension).

NewLeaf potatoes, with the Bt trait alone, were the first genetically engineered potato varieties that were made available to growers, in 1996. NewLeaf varieties only provide control of CPB. The best fit for these varieties would be in the Eastern states, where CPB is the primary insect pest and PLRV is not a concern. Surveyed growers who planted both NewLeaf and conventional Russet Burbank potatoes in 1998 made 1.35 fewer insecticide applications on their NewLeaf fields. In terms of total amount of insecticides used, NewLeaf fields required 0.48 lbs/acre less insecticide active ingredient. Eastern growers had the greatest reduction in the number of insecticide applications, from 3.12 to 1.77. Table 25 shows the results of a grower survey conducted by Monsanto comparing insecticide use on NewLeaf and conventional potatoes.

In the Pacific Northwest, growers who adopted the technology were those with a history of light infestation of pests other than CPB. The New Leaf potato technology fee was about $30 per acre in 1998. Avoiding an at-plant insecticide application cost of $60 per acre represented a saving of $30 per acre. If only one foliar application was needed during the year for aphids at a cost of $20 per acre, the grower could save $10 per acre. Some of the growers planting New Leaf were interested in supporting and trying the technology while others selected the New Leaf varieties for agronomic considerations.

Most growers did not change their insect control practices and still used the at-planting systemic insecticide.

The introduction of NewLeafPlus and NewLeafY potato varieties, with built-in virus protection in addition to protection against CPB, had the potential to provide growers with greater benefits in terms of reducing the need for insecticide treatments. NewLeafPlus and NewLeafY do not control the aphids that vector PLRV and PVY, but are protected from these viruses that the aphids transmit. NewLeafPlus varieties are most valuable for growers in the Pacific Northwest, where PLRV is prevalent and destructive. In field trials conducted by NatureMark in 1998 and 1999, fewer insecticide applications were made to NewLeafPlus fields than to conventional Russet Burbank fields. Table 26 shows the average number of insecticide applications made to NewLeafPlus fields compared to conventional fields. NewLeafPlus potatoes are also expected to reduce losses due to net necrosis. In total, growers could save considerably in reduced losses due to net necrosis and in reduced insecticide costs. Including the $46 per acre technology fee for NewLeafPlus varieties, field trial results indicate an average savings of $85 per acre in 1998 and $134 per acre in 1999. (See Table 27.)

NewLeafY potato varieties are expected to provide benefits both in the production of certified seed potatoes as well as for commercial growers. Potatoes grown for seed are certified by state agencies against viral infection. The availability of NewLeafY potatoes eliminates the need for pest control targeted at the PVY, and allows growers to produce seed free of PVY.

Table 24. Insecticide Use in U.S. Fall Potato Production 1999

	Percent of Acres Treated	Total Applied (1,000 lbs)
Aldicarb	5	141
Azinphos-methyl	7	38
Carbaryl	3	30
Carbofuran	10	204
Cyfluthrin	3	**
Diazinon	2	31
Dimethoate	13	100
Disulfoton	1	19
Ethoprop	8	331
Endosulfan	16	221
Esfenvalerate	16	9
Fonofos	1	30
Imidacloprid	34	55
Malathion	*	2
Methamidophos	29	520
Methyl parathion	1	12
Oxamyl	2	13
Permethrin	8	15
Phorate	23	691
Phosmet	4	32
Piperonyl butoxide	2	22
Propargite	4	76
Spinosad	3	2
Total	**93**	**2,596**

*less than 1% of acres treated
** less than 1,000 lbs. applied
Source: USDA NASS

Table 25. Insecticide Use in NewLeaf and Conventional Potatoes 1998

		Russet Burbank		NewLeaf		Difference	
Region	**# of Farms Sampled**	**# of Insecticide Applications**	**Insecticide Use (lbs/acre)**	**# of Insecticide Applications**	**Insecticide Use (lbs/acre)**	**# of Insecticide Applications**	**Insecticide Use (lbs/acre)**
East	3	3.33	1.89	1.67	1.29	1.66	0.6
Midwest	15	3.85	1.60	2.58	1.73	1.27	-0.13
Idaho	14	1.56	3.25	0.53	1.69	1.03	1.56
Columbia Basin	4	4.00	6.16	3.25	4.53	0.75	1.63
Average	35	3.12	2.43	1.77	1.95	1.35	0.48

Note: Survey results from 35 farms representing all potato production regions.

Source: Owens

Table 26. Average Number of Insecticide Treatments for Conventional and NewLeafPlus Potatoes

	1998	1999
Russet Burbank	5.3	5.3
NewLeafPlus	1.0	3.2

Note: Results from field trials conducted in 8 locations in 1998 and 6 locations in 1999.
Source: Owens

Table 27. Average Costs from Net Necrosis and Insecticides for Conventional and NewLeafPlus Potatoes

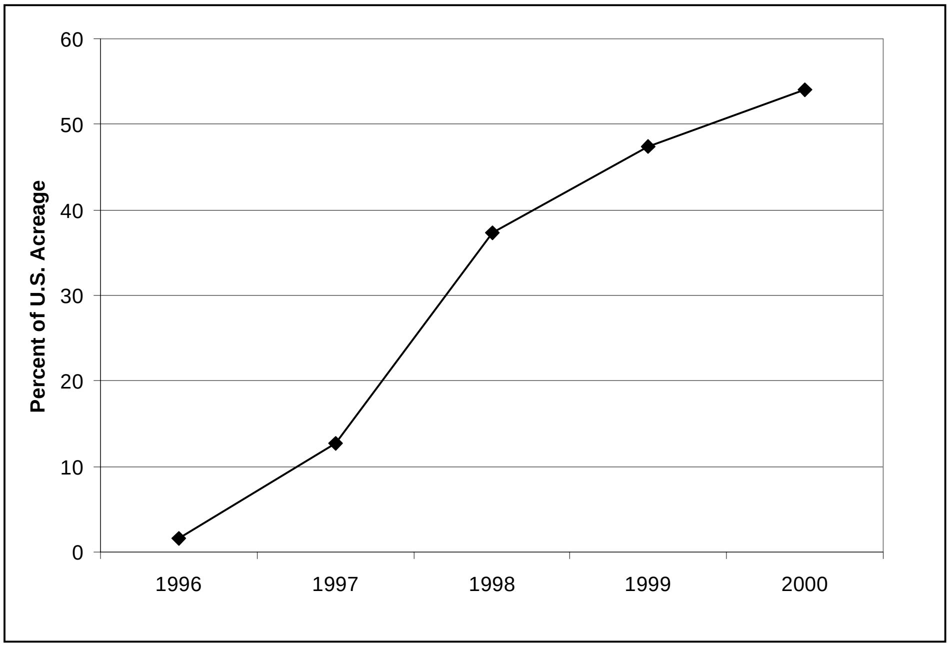
	1998		1999	
	Russet Burbank	**NewLeaf Plus**	**Russet Burbank**	**NewLeaf Plus**
	$/acre		$/acre	
Net Necrosis	44	4	122	1
Insect Control	114	68	98	85
Total	**157**	**72**	**220**	**86**

Note: Insect control costs include all insecticides and for NewLeafPlus, a $46 per acre technology fee. Results from field trials conducted in 8 locations in 1998 and 6 locations in 1999.
Source: Owens

Soybeans

Roundup Ready soybean varieties were introduced for planting by U.S. farmers in 1996, allowing treatment of a growing soybean crop with glyphosate (Roundup). Roundup Ready soybeans have been widely adopted by U.S. growers. Figure 10 shows adoption rates since 1996 in the U.S. By 2000, growers planted 54% of U.S. soybean acreage to glyphosate tolerant soybeans (USDA NASS 2000a).

Figure 10. Glyphosate Tolerant Soybean Adoption



Sources: Marshall, USDA NASS 2000a

Soybean is the second largest crop in the U.S. after corn, planted on 74.5 million acres in 2000 (USDA NASS 2000a). Acreage planted to soybean has expanded in recent years due to several factors. Improved yields through variety improvements, adoption of moisture-saving no-till practices, strong soybean prices relative to other crops, and elimination of acreage reduction programs are all factors that have contributed to expanded plantings. Total soybean crop value in 1999 was $13 billion (USDA ERS 1999).

Soybean acreage is centered in the Midwestern states, though 30 states have significant acreage planted to soybeans each year. Illinois and Iowa each plant over 10 million acres of soybeans. Other major soybean states include Minnesota, Indiana, Missouri and Ohio (USDA NASS 2000a).

The U.S. is the largest producer of soybeans in the world, growing nearly half of the total world soybean crop. Other major producing countries include Brazil, China and Argentina. The U.S. exports approximately one-third of its soybean production, primarily to Asia and Europe, which together account for over 70% of total exports. Competition in export markets comes from Brazil and Argentina, as China is a net importer of soybeans (USDA NASS 2000b).

The primary reason growers have adopted Roundup Ready weed control programs is the simplicity of a weed control program that relies on one herbicide to control a broad spectrum of weeds without crop injury or crop rotation restrictions. Before the introduction of Roundup Ready soybean varieties, growers would choose between many herbicides, often applying three or more active ingredients, some of which would cause damage to the growing soybean plants, or cause harm to corn crops that commonly follow soybeans (Gianessi, et al. 2000).

Roundup is a highly effective, broad spectrum herbicide that controls both broadleaf and grass weeds. Each year, state extension services release weed control guides for field crops including soybeans. The guides provide information on the efficacy of available herbicide treatments on specific weed species, as well as ratings of crop safety. In the Michigan State University weed control guide, in which 182 treatments are rated on 24 different weed species, Roundup, used over Roundup Ready soybeans received 23 good or excellent ratings. In addition, the Roundup treatment is rated with a minimal risk of crop injury. The next best available treatment with similar crop safety received only 16 good or excellent ratings (Kells, et al.).

Growers also have more flexibility in timing herbicide treatments with the Roundup Ready system. Maximum weed heights at which Roundup is effective on most weed species are higher than other available herbicides. This allows growers to treat later if needed and still get effective weed control. Further, some commonly used soybean herbicides may cause injury to rotation crops. Because of this potential for injury to crops following soybeans, rotation restrictions are specified on the labels of these herbicides. For instance, sugarbeets may not be planted for 40 months after a field is treated with imazethapyr, a commonly used soybean herbicide.

Potential impacts of adopting Roundup Ready weed control programs include changes in costs, yields and pesticide use. Roundup Ready programs were introduced to be price competitive with existing conventional programs. The introduction of competitively priced Roundup Ready programs resulted in manufacturers of other products dropping their prices, in some cases by 40%. This resulted in an estimated $216 million cost savings for soybean growers in 1999 compared to 1995, the year before Roundup Ready varieties were introduced, including the technology fee paid by growers who planted Roundup Ready varieties. Table 28 shows estimated soybean weed control program costs for 1995, 1998 and 1999.

Table 28. Soybean Weed Control Costs

	1995	1998	1999
		millions	
Herbicide Expenditures	$1,865	$1,482	$1,441
Technology Fee	$0	$160	$208
Net Weed Control Costs	$1,865	$1,642	$1,649

Note: Calculated assuming herbicide expenditures in 13 states represent 80% of U.S. total.

Herbicide use in soybeans has been affected dramatically by the introduction of Roundup Ready soybean varieties. The mix of herbicides being used in soybeans has changed. As one would expect, the use of glyphosate has increased, from being used on 20% of acreage in 1995 as a burndown or spot treatment, to being used on 62% of acres in 1999. The use of other herbicides has decreased. Imazethapyr, the most widely used soybean herbicide in 1995, was used on 44% of soybean acres in 1995, compared to 16% in 1999. Table 29 shows use estimates of individual soybean herbicides in 1995 and 1999.

USDA pesticide use estimates show an increase in the total amount of herbicides used in soybean production, which is at least partially due to increased acreage. (See Figure 11.) Herbicide application rates are the same in 1999 as in 1995. Table 30 shows applications rates for 8 states since 1990. Growers have reduced the number of herbicide applications. Comparing 1995, the year before Roundup Ready varieties were introduced, and 1999, the last year for which data are available, the number of herbicide applications decreased by 19 million, or 12%. These changes in herbicide use occurred even though the total number of soybean acres increased by 18% between 1995 and 1999. The decrease in herbicide applications demonstrates growers using fewer active ingredients and making fewer trips over the field, which translates into ease of management.

The benefits of the introduction of Roundup Ready soybeans include a cost savings of $216 million in annual weed control costs and 19 million fewer soybean herbicide applications per year.

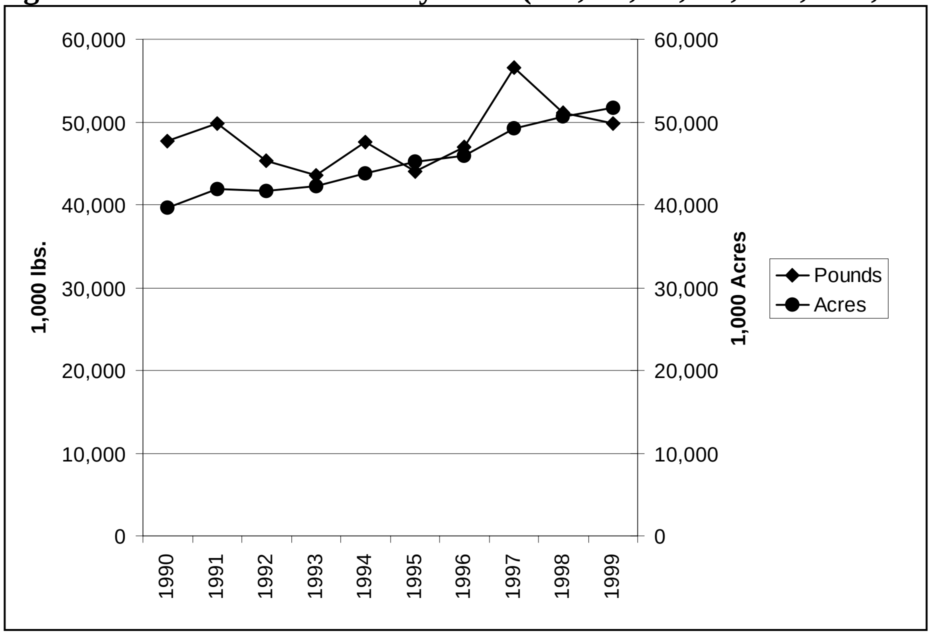
Table 29. Soybean Herbicide Use 1995 and 1999

Active Ingredient	1995	1999
	percent of acres treated	
2,4-D	10	5
2,4-D,B	1	*
Acifluorfen	12	3
Alachlor	4	2
Bentazon	12	4
Chlorimuron	16	12
Clethodim	5	5
Clomazone	4	1
Cloransulam		5
Dimethenamid	1	*
Ethalfluralin	1	*
Fenoxaprop	6	4
Fluazifop	10	4
Flumetsulam	2	2
Fomesafen	4	4
Glyphosate	20	62
Imazamox		3
Imazaquin	15	5
Imazethapyr	44	16
Lactofen	5	2
Linuron	2	*
Metolachlor	7	4
Metribuzin	11	5
Paraquat	2	1
Pendimethlin	26	14
Quizalofop	6	1
Sethoxydim	7	3
Sulfentrazone		4
Thifensulfuron	12	5
Trifluralin	20	14

Source: USDA NASS

* less than 1%

Figure 11. Herbicide Use in Soybeans (AR, IA, IL, IN, MN, MO, NE, OH)



Source: USDA NASS 1991-2000

Table 30. Soybean Herbicide Application Rates (AR, IA, IL, IN, MN, MO, NE, OH)

Year	Rate (lbs/acre)
1990	1.26
1991	1.23
1992	1.11
1993	1.06
1994	1.11
1995	1.00
1996	1.05
1997	1.18
1998	1.06
1999	1.00

Source: USDA NASS

Summary

The reasons U.S. growers are adopting genetically modified crops vary. The fact that new genetically modified varieties are capturing a large portion of the very competitive pesticide markets for major crops indicates that the new technology is delivering benefits to growers.

Bt corn varieties have provided control of a destructive insect pest that was mostly uncontrolled previously, which has resulted in increased yields. Cotton growers have adopted varieties that are insect and/or herbicide tolerant, which has allowed reduced pesticide use, increased yields and increased grower returns. Potato growers have not yet widely adopted Bt varieties. Soybean growers have adopted Roundup Ready soybeans largely due to the simplicity and efficacy of weed control provided by the program. The result has been soybean herbicide cost savings and a significant reduction in the number of soybean herbicide treatments.

References

Benttari, Ernest E., "Management of Diseases Caused by Viruses and Viruslike Pathogens," Potato Health Management, American Phytopathological Society Press, 1993.

Bishop, G.W., et al., Management of Potato Insects in the Western States, Western Regional Extension Publication, WREP 64, 1982.

Brecke, Barry J., University of Florida, unpublished data.

Bridges, David C., University of Georgia, unpublished data.

Briggs, S.P. and C.A. Guse, "Forty Years of European Corn Borer Data: What Have We Learned?" 38th Illinois Custom Spray Operators Training Manual, Cooperative Extension Service, University of Illinois, 1986.

Byrd, J.D. Jr., "Report of the 1998 Cotton Weed Loss Committee," 1999 Beltwide Cotton Conferences.

Carpenter, Janet E. and Leonard P. Gianessi, "Value of Bt and Herbicide-Resistant Cottons," 2000 Beltwide Cotton Conferences.

Casagrande, R.A., "The Colorado Potato Beetle: 125 Years of Mismanagement," Bulletin of the ESA, 1987.

Coble, Harold D., "Genetically Engineered Cotton," Environmental Benefits and Sustainable Agriculture Through Biotechnology, Georgetown University, Washington, D.C., November 19, 1999.

Cooke, F.T., et al., "The economics of Bt cotton in the Mississippi Delta–a progress report," 2000 Proceedings Beltwide Cotton Conference.

Cornell Cooperative Extension, 1999 Integrated Crop and Pest Management Recommendations for Commercial Vegetable Production.

Ferro, David N., and Gilles Boiteau, "Management of Insect Pests," Potato Health Management, American Phytopathological Society Press, 1993.

Gianessi, Leonard P. and Janet E. Carpenter, Agricultural Biotechnology: Insect Control Benefits, National Center for Food and Agricultural Policy, 1999.

Gianessi, Leonard P. and Janet E. Carpenter, Agricultural Biotechnology: Benefits of Transgenic Soybeans, National Center for Food and Agricultural Policy, 2000.

Gray, Mike and Kevin Steffey, "European Corn Borer Population in Illinois Near Historic Low," Pest Management and Crop Development Bulletin, University of Illinois Extension, no. 24, 1999.

Hayes, Robert M., University of Tennessee, personal communication, 1999.

Hayes, Robert M., University of Tennessee, unpublished data.

Hooker, W.J. (ed.), Compendium of Potato Diseases, American Phytopathological Society, 1981.

Karner, M., et al., "Bollgard–Impact and value to Oklahoma's cotton industry," 2000 Proceedings Beltwide Cotton Conference.

Kells, James J. and Karen A. Renner, 1999 Weed Control Guide for Field Crops, Michigan State University, Extension Bulletin E-434.

Kilman, Scott, "Monsanto's Biotech Spud Is Being Pulled From the Fryer at Fast-Food Chains," Wall Street Journal, April 28, 2000.

Marshall, Karen, Monsanto, personal communication, 2000.

Michigan Potato Industry Commission and the Potato Growers of Michigan, Inc., 1998 Michigan Potato Pest Survey.

Miller, Donnie K., Louisiana State University, unpublished data.

Monsanto, "YieldGard: The Whole Plant The Whole Season," 1999.

Mullins, Walt, Monsanto, personal communication, 2000.

Murdock, Ed, Clemson University, personal communication, 1999.

Owens, Elizabeth, Monsanto, personal communication, 2000.

Pacific Northwest Insect Control Handbook 1999.

Reed, J.T., et al., "Bt and conventional cotton in the hills and delta of Mississippi: 5 years of comparison," 2000 Proceedings Beltwide Cotton Conference.

Rowe, Randall C. (ed.), Potato Health Management, American Phytopathological Society, 1993.

Schreiber, Alan, and Laura Ritchie, Washington Minor Crops, Washington State University.

Seward, R.W. and P.P. Shelby, "Performance and insect control cost of Bollgard vs. Conventional Varieties in Tennessee," 2000 Proceedings Beltwide Cotton Conference.

Snipes, Charles E., Mississippi State University, unpublished data.

Steffey, Kevin, "A Flurry of European Corn Borer Activity, and Bt Corn for 1999?" Pest Management and Crop Development Bulletin, University of Illinois, no. 22, 1998.

Thomas, P.E., et al., "Reduced Field Spread of Potato Leafroll Virus in Potatoes Transformed with the Potato Leafroll Virus Coat Protein Gene," Plant Disease, December 1997.

USDA Agricultural Marketing Service, Cotton Varieties Planted, various issues.

USDA Animal and Plant Health Inspection Service, Cooperative Economic Insect Report, vol. 25, no. 32, 1975.

USDA Economic Research Service, 1997, Pest Management on Major Field Crops, AREI Updates, Number 1.

USDA Economic Research Service, 1999, Oil Crops Situation and Outlook.

USDA National Agricultural Statistics Service, Acreage, 2000a.

USDA National Agricultural Statistics Service, Agricultural Chemical Usage: Field Crops Summary, various issues.

USDA National Agricultural Statistics Service, Agricultural Statistics, 2000b.

USDA National Agricultural Statistics Service, Crop Production, 2000c

USDA National Agricultural Statistics Service, Crop Values, 2000d.

US Environmental Protection Agency, "Bromoxynil; Pesticide Tolerance," Fed. Reg. vol. 63, no. 92, p. 26,473, May 18, 1998.

US Environmental Protection Agency, "Biopesticides Registration Action Document: Preliminary Risks and Benefits Sections Bacillus thuringiensis Plant-Pesticides," Office of Pesticide Programs, Biopesticides and Pollution Prevention Division, 2000.

Whalon, Mark, and David Ferro, "Bt-Potato Resistance Management," Now or Never: Serious New Plans to Save a Natural Pest Control, Union of Concerned Scientists, 1998.

Wilcut, John W., North Carolina State University, unpublished data.

Williams, Michael R., "Cotton Insect Losses," Beltwide Cotton Conferences, various issues.

This report updates previous estimates of aggregate benefits resulting from farmersâ€™ adoption of genetically modified varieties for corn, cotton, potatoes and soybeans. The aggregate impacts of the introduction of genetically modified crop varieties are summarized in tables 2-5. These tables present aggregate estimates of changes in net revenue, increases in production, decreases in pesticide use and decreases in pesticide acre treatments. Table 1. Adoption of Genetically Modified Varieties in the U.S. 1995 1996 1997 1998 1999 2000.Â Gianessi, Leonard P. and Janet E. Carpenter, Agricultural Biotechnology: Benefits of Transgenic Soybeans, National Center for Food and Agricultural Policy, 2000. 43. Hence, agricultural biotechnology benefits the environment by increasing production yields. In this way, reduces pressures to force more land into production, often highly erodible and marginal land. Another benefit is the use of biotech herbicide-tolerant crops which allow the use of no-till farming practices. Biotechnology limits carbon dioxide emissions reduce erosion and improves soil moisture content. By using biotech crops, agricultural biotechnology will make use of fewer applications of pesticides. Hence, it will reduce on-farm energy consumption and several other associated environmental impacts. Furthermore, this technology reduces waste production from livestock feedlots. Agricultural biotechnology is a set of tools and disciplines meant to modify organisms for a particular purpose. That purpose can include anything from coaxing greater yields from food crops to building in a natural resistance to certain diseases. Though there are multiple ways to accomplish this goal, the method that tends to get the most attention from the public is genetic modification.Â Agricultural biotechnology lets scientists pick and choose which genes are introduced to an organism. Let's take a look at some of the benefits of this technology. Advertisement. Benefits of Agricultural Biotechnology. The applications of agricultural biotechnology are nearly limitless. Your own diet may include many products that are the result of agricultural biotechnology projects. Agricultural biotechnology is a range of tools, including traditional breeding techniques, that alter living organisms, or parts of organisms, to make or modify products; improve plants or animals; or develop microorganisms for specific agricultural uses. Modern biotechnology today includes the tools of genetic engineering. 2. How is Agricultural Biotechnology being used?Â The application of biotechnology in agriculture has resulted in benefits to farmers, producers, and consumers. Biotechnology has helped to make both insect pest control and weed management safer and easier while safeguarding crops against disease. 2001. Agricultural Biotechnology: Updated Benefits Estimates . National Center for Food and Agricultural Policy, Washington, D.C. Google Scholar. Conway, G. 2000. Crop Biotechnology: Benefits, Risks and Ownership . Speech by the President of the Rockefeller Foundation delivered at the OECD Edinburgh Conference on the Scientific and Health Aspects of Genetically Modified Foods. Available online under â€œnews archiveâ€ at http://www.rockfound.org (accessed March 2004).