Quantification of the Impacts on US Agriculture of Biotechnology-Derived Crops Planted in 2005

November 2006

Sujatha Sankula Ph.D

National Center for Food and Agricultural Policy
1616 P-street, NW
Washington, DC 20036
Phone: 202-328-5048
Fax: 202-328-5133
Email: ncfap@ncfap.org
Website: www.ncfap.org

Table of Contents

Introduction

Crops developed through biotechnology methods have been embraced at an astonishing speed across the world since their first commercial planting in 1996. Planted acreage reached 222 million acres in 2005, a year which is considered remarkable in the history of agriculture and biotechnology, as it represented two significant milestones. First, it marked the first decade of the planting of biotechnology-derived crops. Second, it denoted the historic event of the planting of the first billionth acre (cumulative) to biotechnology-derived crops. It is estimated that some farmer in the world planted the one-billionth acre to these crops in May 2005.

Approximately 8.5 million farmers from 21 different countries planted biotechnology-derived crops in 2005 (James 2006). The 21 countries are Argentina, Australia, Brazil, Canada, China, Columbia, Czech Republic, France, Germany, Honduras, India, Iran, Mexico, Paraguay, Philippines, Portugal, Romania, South Africa, Spain, United States, and Uruguay. Four countries, Czech Republic, France, Iran, and Portugal, planted these crops for the first time in 2005. Also, it is remarkable to note that 9 of the above-listed 21 nations are developing countries.

The 2005-planted acreage of 222 million acres represented an 11% rise in adoption compared to 2004 (200 million acres) (James 2005; James 2006). Additionally, the year 2005 witnessed 24% increase in the number of countries that planted these crops (17 countries in 2004 versus 21 countries in 2005).

The United States continued to lead the world in the adoption of biotechnology-derived crops in 2005 with about 123 million acres or 55% of the total global planted area. Planted acreage in 2005 was mainly concentrated in three commercialized applications (virus-resistance, herbicide-resistance, and insect-resistance or Bt) and eight crops (alfalfa, canola, corn, cotton, papaya, soybean, squash, and sweet corn). Approximately 93, 52, 79, 55, 88, and 12% of the total acreage of canola, corn, cotton, papaya, soybean and squash, respectively, was planted to biotechnology-derived varieties in the United States in 2005. Biotechnology-derived alfalfa and sweet corn were planted on a very minor acreage (<1%) in 2005.

Positive impacts that stemmed from the technology served as the primary driving force behind the increased adoption of these crops each year across the globe and throughout the United States as well. As a matter of fact, a recent report from North Dakota State University suggests that biotechnology is among the key forces reshaping world agriculture, enabling increased crop yields and productivity despite limited available land, and leading to better quality and lower priced food products for consumers (Mattson and Koo 2006).

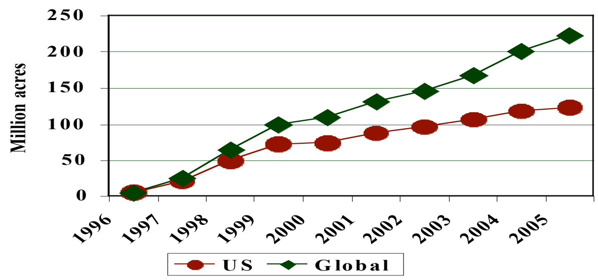
In spite of the proven fact that biotechnology-derived crops are economically viable, environmentally sustainable, and are as safe as, if not safer, than their conventional counterparts, the debate over agricultural biotechnology and its applications continues to transpire. The debate continues to focus mainly on hypothetical risks and questions related to value, safety, and impacts (agronomic, economic, and environmental) of biotechnology-derived crops.

The National Center for Food and Agricultural Policy (the National Center) continues to play an active role in the biotechnology debate by addressing key issues of significance to various stakeholders. Three previous reports from the National Center that assessed the agronomic, economic, and environmental impacts of biotechnology-derived crops planted in 2001 (Gianessi et al., 2002), 2003 (Sankula and Blumenthal 2004), and 2004 (Sankula et al. 2005) attracted extensive press and national attention. These reports are frequently cited in university publications, peer reviews, and popular press in addition to being used in classroom curriculum. In view of the value, interest, and positive response generated from these reports, the National Center embarked on a fourth report to quantify the impacts of biotechnology-derived crops based on 2005 growing season, acreage, and crop production information. The current report, therefore, is a follow-up to Impacts on U.S. Agriculture of Biotechnology-Derived Crops Planted in 2004 - An Update of Eleven Case Studies, released in December 2005. Information generated from this report is critical to biotechnology debate and policy discussions to facilitate better-informed decision-making.

Numerous changes have occurred since the release of the National Center's last report. Both the planted acreage and available applications increased since 2004. American growers increased the planting of biotechnology-derived crops on 5 million or 4% more acres in 2005, compared with 2004. Though the number of biotechnology-derived crop traits (herbicide-resistance, insect-resistance or Bt, and virus-resistance) remained the same in 2005, similar to 2004, the total number of planted applications increased to thirteen in 2005 (from twelve in 2004). All the planted applications in 2005 were listed in Table 1 of the Method section. Increase in number of applications is due to a new biotechnology-derived crop, alfalfa (herbicide-resistant/glyphosate-resistant), which was first available for commercial planting in 2005. Other noteworthy changes for 2005 crop season include the commercial debut of Roundup Ready Flex cotton and WideStrike cotton. While Roundup Ready Flex cotton offers expanded window for over-the-top application of Roundup herbicide, WideStrike cotton provides enhanced control of worm pests such as cotton bollworm, tobacco budworm, beet armyworm, fall armyworm, soybean loopers, cabbage loopers, and pink bollworm.

The purpose of this report is to document the changes that occurred during the 2005 planting season, quantify the impacts of these changes, and update the impact estimates of biotechnology-derived crops planted in 2005. This report attempts to provide an economic perspective and establish the basis to understand why American farmers have embraced biotechnology and are likely to continue to do so. Other impacts on production practices such as tillage are also discussed.

Figure 1: Acreage planted to biotechnology-derived crops



References

Gianessi, L. P., C. S. Silvers, S. Sankula, and J. E. Carpenter. 2002. Plant biotechnology: current and potential impact for improving pest management in US agriculture, an analysis of 40 case studies. Available at www.ncfap.org/whatwedo/biotech-us.php.

James, C. 2006. Global Area of Biotech Crops, 1996 to 2005: by Country. Available at http://www.isaaa.org/kc/CBTNews/press_release/images/briefs34/figures/acres/by%20country_acres.jpg. ISAAA Briefs 34-2005.

James, C. 2005. Global status of commercialized biotech/GM crops: 2004. ISAAA Briefs 32-2004.

Mattson, J. and W. Koo. 2006. Forces reshaping world agriculture. North Dakota State University's Agribusiness And Applied Economics Report No. 582. Available at http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid= 21789&ftype=.pdf

Sankula, S. and E. Blumenthal. 2004. Impacts on US agriculture of biotechnology-derived crops planted in 2003: An update of eleven case studies. Available at http://www.ncfap.org/whatwedo/biotech-us.php.

Sankula, S., G. Marmon, and E. Blumenthal. 2005. Biotechnology-derived crops planted in 2004 - Impacts on US agriculture. Available at http://www.ncfap.org /whatwedo/ biotech-us.php.

Method

The objective of this report is to evaluate and quantify the impacts on US agriculture of biotechnology-derived crop cultivars planted in the tenth year of their commercial cultivation. Table 1 depicts the trait information for the 8 biotechnology-derived crops (alfalfa, corn, cotton, canola, papaya, squash, soybean, and sweet corn) planted in 2005.

Impacts were analyzed for only 6 crops (corn, cotton, canola, papaya, squash, and soybean) in this report. Impacts were not analyzed for alfalfa and sweet corn in view of their limited acreage in 2005. Furthermore, fall-planted alfalfa will be harvested in 2006 and therefore it technically belongs to the 2006 crop year even though 2005 was the first year of its commercial planting.

Information was analyzed and updated for ten case studies (Table 2). Though there were only 6 planted biotechnology-derived crops, crops such as corn and cotton had more than one pest management trait in commercial production, which led to ten case studies. Unlike the last report, case study on Herculex I corn is not included in this report.

This report does not detail the background information on each case study as the status of the pest problems and conventional pest management practices have more or less remained unchanged since our earlier reports released in 2002, 2004, and 2005. Background information for all the case studies of this report can be obtained from the earlier reports, which can be accessed at http://www.ncfap.org/whatwedo/40casestudies.php and http://www.ncfap.org/ whatwedo/biotech-us.php.

Similar to the earlier reports, states for which pest management would be impacted due to the adoption of the biotechnology-derived crop cultivars were identified and impacts were quantified. For some case studies (example: virus-resistant squash and herbicide-resistant canola), only certain states were used in the analysis. These states were those with either largest crop acreage or states where the technology could provide maximum impact in view of the significance of the pest problem. Thus, geographical analysis was limited in scope for some crops.

Similar to the method used in the earlier report, the effectiveness of the biotechnology-derived crops in controlling the target pest(s) and the resulting impacts on production practices and pest management were calculated. Impacts were identified and quantified in four categories. They include changes in production volume, value, costs, and pesticide use. Crop production statistics complied by the United States Department of Agriculture's National Agricultural Statistics Service served as a valuable resource for the determination of the above impacts.

Changes in production volume were measured based on yield changes that have occurred when biotechnology-derived crops replaced existing production practices. Changes in production value were calculated based on yield changes and crop prices. Changes in production costs were calculated by determining which current practices would be affected. Adoption costs associated with use of the technology (either as royalty/technology fee or seed premium or both) were considered in these calculations. Finally, changes in pesticide use were quantified when the biotechnology-derived crop cultivar has replaced or substituted current use of the target pesticides leading to either an increased or reduced usage. All the above impacts were calculated using acreage and other production information for 2005.

In addition to the above-discussed impacts, changes and new developments in pest management (such as newly approved biotechnology applications) and other production practices that followed biotechnology-derived crops were also discussed in this report. One of these changes is the increased adoption of no-tillage practices that has taken place subsequent to the widespread planting of herbicide-resistant crop varieties. Changes in no-till acres were analyzed in this report.

University researchers and Extension Crop Specialists were surveyed to evaluate existing pest management approaches in conventional crops and to determine how biotechnology-derived crops replaced or substituted current practices. Pesticide-use information and pest-loss reports were also examined. Updated estimates, in a case study format, were sent to relevant external reviewers for comment. Comments and suggestions from the reviewers were integrated into the final version of the report.

Table 1: Biotechnology-derived crops planted in the United States in 2005

Trait	Crop	Resistance to	Trade name
Virus-resistant	Papaya	Papaya ring spot virus	-
Virus-resistant	Squash	Cucumber mosaic virus, Watermelon mosaic virus, Zucchini yellows mosaic virus	-
Herbicide-resistant	Soybean	Glyphosate	Roundup Ready
Herbicide-resistant	Canola	Glyphosate Glufosinate	Roundup Ready Liberty Link
Herbicide-resistant	Corn	Glyphosate Glufosinate	Roundup Ready Liberty Link
Herbicide-resistant	Cotton	Glyphosate Glufosinate	Roundup Ready; Roundup Ready Flex Liberty Link
Herbicide-resistant	Alfalfa	Glyphosate	Roundup Ready
Insect-resistant	Corn	European corn borer/Southwestern corn borer/corn earworm European corn borer/southwestern corn borer/black cutworm/fall armyworm/corn earworm Rootworm	YieldGard Corn Borer Herculex I YieldGard RW
Insect-resistant	Cotton	Bollworm/budworm Bollworm/budworm/looper/armyworm	Bollgard Bollgard II WideStrike
Insect-resistant	Sweet corn	European corn borer/corn earworm	Attribute

Table 2. Case studies for which impacts were analyzed for 2005 crop season

Case study	Crop	Trait
1	Papaya	Virus-resistant
2	Squash	Virus-resistant
3	Canola	Herbicide-resistant
4	Corn	Herbicide-resistant
5	Cotton	Herbicide-resistant
6	Soybean	Herbicide-resistant
7	Corn	Insect-resistant (IR-I)[a]
8	Corn	Insect-resistant (IR-II)[b]
9	Cotton	Insect-resistant (IR-III)[c]
10	Cotton	Insect-resistant (IR-IV)[d]

[a]European corn borer/southwestern corn borer/corn earworm-resistant corn (YieldGard Corn Borer)

[b]Rootworm-resistant corn (YieldGard RW)

[c]Bollworm and budworm-resistant cotton (Bollgard)

[d]Bollworm/budworm/looper/armyworm-resistant cotton (Bollgard II)

Virus-resistant crops

The two biotechnology-derived virus-resistant crops that were grown commercially in the United States in 2005 were still papaya and squash. The following section is an update on the impacts based on their planted acreage in 2005.

1. Papaya

The number of acres on which biotechnology-derived virus-resistant papaya was planted in Hawaii (the primary papaya producing state in the United States) continued to increase in 2005. Virus-resistant papaya varieties were planted on approximately 55% of the total acreage in 2005 (Table 1.1). Based on number of acres planted, this is roughly 12% higher adoption than that noted in 2004.

Similar to 2004, Hawaiian growers planted three biotechnology-derived virus-resistant papaya varieties in 2005. They include 'Rainbow', 'Sunup', and 'Laie Gold.' Rainbow variety remained the most popular, accounting for 96% of the acreage planted to biotechnology-derived varieties and 53% of all papaya planted in 2005. The dominance of Rainbow variety is due to its ability to withstand ringspot virus infestations, higher yield potential, and yellow colored flesh preferred by papaya growers and marketers (Gonsalves 2005). Sunup and Laie Gold were planted on 20 acres each or less than 1% each of the total planted papaya acreage in 2005 (Fitch 2006). The adoption of Sunup is low due to its commercially undesirable characteristics such as red flesh and its susceptibility to fungal pathogens (Fitch 2006).

Laie Gold is currently being grown commercially on farms smaller than 30 acres and is generally sold in higher-priced niche markets. Adoption of Laie Gold has not reached commercial levels yet as available seed supply is very limited and growers are still experimenting with this variety (Fitch 2006). Adoption estimates for 2005 indicate that acres planted to Laie Gold continued to increase (12 acres in 2004 to 20 acres in 2005) due to its favorable characteristics such as its sweet mango-and-coconut flavor, thick orange-yellow flesh, attractive globular shape, and higher market price (Fitch 2006).

The impacts of biotechnology-derived papaya are presented in Table 1.2. Calculations within this table, similar to the earlier report, were based on the hypothesis that any changes in crop production since 1998 (the year when biotechnology-derived papaya varieties were first commercially planted) have resulted from the introduction of biotechnology derived virus-resistant varieties.

Similar to the years since 1998, per acre papaya yields continued to increase in 2005 also. However, increase in per acre yields was only 18% in 2005 (compared to 1998) whereas yield improvement was 53% in 2004 (Table 1.2). In spite of 11% increase in the bearing acreage of Rainbow in 2005, overall papaya production in 2005 decreased by 23% compared to 2004. Dry weather and irregular rainfall during flowering and fruit maturation in 2005 has contributed to reduced flowering and gaps in fruit on columns (fruiting stalks) and eventual yield decline (Hawaii Agricultural Statistics Service 2005 Year Book). Regardless, planting of biotechnology-derived virus-resistant varieties has increased crop production by 4.5 million pounds in 2005 (compared to 1998) and the farm gate value of this increased production was $1.7 million.

Papaya growers had to pay for seeds of biotechnology-derived varieties in 2005 as in 2003 and 2004. Since the discontinuation of the Papaya Administrative Committee (PAC)'s Federal Marketing Order in 2002, the Hawaii Papaya Industry Association has set the seed costs for biotechnology-derived varieties. Similar to 2004 and 2003, the seed and distribution costs for biotechnology-derived papaya were set at $20 per ounce (Perry 2006). Typically, papaya growers use 5 ounces of seed to plant an acre (Perry 2006). Therefore growers that planted biotechnology-derived varieties incurred about $100/acre on seed costs in 2005. Based on conventional seed costs of $40/acre (5 ounces of seed per acre at a cost of $8 per ounce of seed) (Uchida 2006), it is estimated that papaya growers paid a total of $79,200 to access biotechnology-derived varieties in 2005. Net returns, calculated by subtracting adoption costs from the value of gained production, were estimated to be $1.6 million in 2005 due to the planting of virus-resistant papaya.

As evidenced by increased adoption in 2005, grower acceptance of biotechnology-derived papaya remains strong in spite of seed premium costs. Adoption will increase further once Japan approves importation of biotechnology-derived papaya.

Table 1.1. Adoption of biotechnology-derived virus-resistant (VR) papaya in Hawaii

Year	Planted papaya acreage	VR papaya acreage as a % of total planted acres[1,2]	VR papaya acres
	Acres	%	Acres
1999	3205	37	1186
2000	2775	42	1166
2001	2720	37	1006
2002	2145	44	944
2003	2380	46	1095
2004	2230	53	1182
2005	2400	55	1320

[1]Comprises of biotechnology-derived ‘Rainbow’, ‘Sunup’, and Laie Gold varieties; Sunup and Laie Gold account for only 1% each of the total planted acreage
[2]Source: Hawaii Agricultural Statistics Service and Hawaii Agricultural Statistics Service 2005 Year Book

Table 1.2. Impact of biotechnology-derived virus-resistant (VR) papaya on crop production

Year	VR papaya acreage	Per acre yields[1]	Increase in per acre yields[2]	Increase in production due to VR varieties[3]	Value of gained production[4]
	Acres	Short ton (=2000 lb)	(%)	000lb	000$
1998	-	9.4	-	-	-
1999	1186	10.9	16	3558	1174
2000	1166	16.6	77	16790	5541
2001	1006	14.1	50	9456	3121
2002	944	13.4	43	7552	2492
2003	1095	13.5	44	8979	2963
2004	1182	14.4	53	11820	4373
2005	1320	11.1	18	4488	1661
Cumulative Total				**62,643**	**21,325**

[1]Source: Hawaii Agricultural Statistics Service
[2]Yield increase was calculated using 1998 as base year
[3]Calculated as difference in per acre yields between 1998 and years when VR varieties were planted times acres on which VR varieties were planted
[4]Estimated per pound cost of papaya in years prior to 2004 = $0.33; cost of papaya per pound in 2004 and 2005 = $0.37 (based on the information from Hawaii Agricultural Statistics Service)

References

Fitch, M. United States Department of Agriculture - Agriculture Research Service. Personal communication. 2006.

Gonsalves, D. United States Department of Agriculture - Agriculture Research Service. Personal communication. 2005.

Hawaii Agricultural Statistics Service. Available at http://www.nass.usda.gov/hi/rlsetoc.htm

Hawaii Agricultural Statistics Service 2005 Year Book.

Perry, D. Hawaii Papaya Industry Association. Personal communication. 2006.

Uchida, R. United States Department of Agriculture - Agriculture Research Service. Personal communication. 2006.

2. Squash

Biotechnology-derived virus-resistant squash is still not as widely planted as other biotechnology-derived crops in 2005, a trend similar to that noted in previous years. Similar to the earlier report, impacts were assessed for seven squash-producing states. These states include Florida, Georgia, Michigan, New Jersey, North Carolina, South Carolina, and Tennessee. Together, the above-listed seven states planted 70% of the total squash acreage in the United States in 2005 (Tables 2.1).

Estimates on acreage planted to biotechnology-derived virus-resistant squash varieties in various states are presented in Table 2.2. Biotechnology-derived squash varieties accounted for 22, 20, 5, 25, 10, 20, and 20% of the total planted acreage in Florida, Georgia, Michigan, New Jersey, North Carolina, South Carolina, and Tennessee, respectively, in 2005. Averaged across the United States, this represents an adoption of 12%. Similar to the years before, high seed costs and lack of resistance to key virus problems such as papaya ringspot virus are the primary reasons for the low adoption of biotechnology-derived squash varieties in the United States.

Based on the typical use rate of 10,000 seeds/acre, average seed cost for conventional squash was $254 per acre in 2005 while biotechnology-derived seeds cost $406 per acre (Infante-Casella 2006). Thus, seed costs for biotechnology-derived varieties were 60% higher compared to conventional varieties. In spite of high seed costs, squash growers planted biotechnology-derived varieties in 2005, primarily as an insurance against yield losses.

Table 2.3 presents the data on the impacts of biotechnology-derived squash varieties in the seven states listed above. It is assumed that biotechnology-derived squash was planted in areas of severe virus infestations and squash growers would experience complete crop (conventional) failure (if not planted with biotechnology-derived varieties) and lose their entire squash production. Therefore, it is assumed that growers that planted biotechnology-derived varieties in 2005 restored their yields to original levels.

Analysis indicates that the impact of biotechnology-derived virus-resistant squash is a gained production of 72 million pounds, valued at $23.3 million. Based on the assumption that American squash growers paid a premium of $1.03 million in seed costs, the net benefit of planting biotechnology-derived varieties was $22.23 million in 2005.

Table 2.1. Acreage and production of US squash in 2005[1]

State[2]	Area planted	Production	Production value
	Acres	Million lb	000$
FL	8,500	107.9	48,555
GA	14,000	136.5	40,404
MI	8,600	153.6	18,531
NJ	3,100	28	7,924
NC	4,000	34	9,860
SC	1,200	6.8	1,460
TN	1,200	8.3	1,516
Total	**40,600**	**475.1**	**128,250**
US total	**58,400**	**814.5**	**210,155**

[1]Source: National Agricultural Statistics Service, Vegetables 2005 Summary
[2]California, New York, Ohio, Oregon, & Texas have squash acreage; however, they were not included in this report

Table 2.2. Adoption of biotechnology-derived virus-resistant squash varieties in 2005

State	Area planted	Adoption of virus-resistant squash	Acreage planted to virus-resistant squash	Source[1]
	Acres	% of total	Acres	
FL	8,500	22	1870	McAvoy
GA	14,000	20	2800	Kelley
MI	8,600	5	430	Zandstra
NJ	3,100	25	775	Infante-Casella
NC	4,000	10	400	Schultheis
SC	1,200	20	240	Boyhan
TN	1,200	20	240	Bost
Total/ Average	**40,600**	**17**	**6,755**	
US Total/ Average	**58,400**	**12**		

[1]Affiliations for the specialists that provided adoption estimates for biotechnology-derived varieties are listed in the References section

Table 2.3. Impacts of biotechnology-derived virus-resistant squash in 2005

State	Acreage planted to virus-resistant squash	Adoption costs[1]	Yield advantage[2]	Gain in value[2]	Net gain
	Acres	$	Million lb	000$	000$
FL	1870	284240	23.7	10682	10398
GA	2800	425600	27.3	8081	7655
MI	430	65360	7.7	927	862
NJ	775	117800	7.0	1981	1863
NC	400	60800	3.4	986	925
SC	240	36480	1.4	292	256
TN	240	36480	1.7	303	267
Total	**6,755**	**1,026,760**	**72.2**	**23,252**	**22,226**

[1]Adoption costs = added seed costs due to biotechnology-derived virus-resistant squash compared to conventional squash. Average costs of conventional and biotechnology-derived squash varieties were $406 and $254 for 10,000 seeds per acre, respectively, in 2005 (Infante-Casella, 2006). Therefore, adoption costs were calculated to be $152 per acre

[2]Yield advantage and gain in value were calculated based on production and production value from Table 2.1 and virus-resistant squash adoption information from Table 2.2

References

Bost, S. University of Tennessee. Personal communication. 2006.

Boyhan, G. University of Georgia. Personal communication. 2006.

Kelley, T. University of Georgia. Personal communication. 2006.

Infante-Casella, M. Rutgers Cooperative Extension of Gloucester County. Personal communication. 2006.

McAvoy, E. University of Florida - Henry County (Extension Agent). Personal communication. 2006.

National Agricultural Statistics Service. Vegetables 2005 Summary: Squash for fresh market and processing: area planted and harvested, yield, production, and value by state and United States, 2005. Available at http://www.nass.usda.gov.

Schultheis, J. North Carolina State University. Personal communication. 2006.

Zandstra, B. Michigan State University. Personal communication. 2006.

Herbicide-resistant crops

With the commercial introduction of glyphosate-resistant alfalfa in 2005, the number of biotechnology-derived herbicide-resistant crops planted in the United States increased by 25% in 2005. Herbicide-resistant crops planted in 2005 in the United States include alfalfa, canola, corn, cotton, and soybean.

Similar to years in the past, herbicide-resistant crops were planted on largest crop acreage of the United States compared to other applications. Herbicide-resistant canola was planted on 93% of the national acreage in 2005, representing the largest adoption for any crop. Herbicide-resistant soybean and cotton also continued to be the dominant crops, with about 88 and 80% adoption, respectively, in 2005. Herbicide-resistant corn was planted on approximately 35% of the total US corn acreage.

Based on the acreage planted, adoption of herbicide-resistant canola, corn, cotton, and soybean increased by 81, 67, 3, and 1%, respectively, in 2005 compared with 2004. Based on percent adoption, on the other hand, increase in the adoption of herbicide-resistant canola, corn, cotton, and soybean was 24, 94, 4, and 4%, respectively, in 2005 compared to 2004. Increased adoption of biotechnology-derived canola in 2005 is attributed to the surging popularity of herbicide-resistant varieties and also overall increase in planted canola acreage in North Dakota, the primary canola producing state in the United States. On the other hand, the significant increase in the adoption of herbicide-resistant corn in 2005 is due to the European Unions' October 2004 approval of glyphosate-resistant corn for use in food products in addition to feed ingredients. It is anticipated that herbicide-resistant corn acreage will further increase in the next few years.

Alfalfa is the first perennial crop that was approved for commercial planting in the United States. Biotechnology-derived glyphosate-resistant alfalfa was developed through a collaborative venture between Monsanto and Forage Genetics International. California, Washington, and Oregon are the three states that planted glyphosate-resistant alfalfa in its first commercial year. In view of limited seed supply (of about 1 million pounds) in the introductory year, it was planted on only 50,000 acres or 0.2% of the total harvested acreage in 2005 (Wilkins 2006). Adoption of glyphosate-resistant alfalfa is increased in 2006, as more seed (of about 3 million pounds) was made available for spring planting.

Growers that planted glyphosate-resistant alfalfa in 2005 had to sign Seed and Feed Use Agreements (SFUA) to ensure that the Roundup Ready alfalfa forage is used only on farms in this country and not grown for export. Per acre technology fee costs were set at $50 in the states east of Rocky Mountains and $60 for states west of Rockies due to greater need for the technology in these states. In view of the perennial nature of the crop, adoption costs will average out to $10 – 15/acre at typical seeding rates and expected stand life (Berg 2005).

Impacts were not analyzed for herbicide-resistant alfalfa in this report because fall-planted alfalfa will be harvested in 2006. Therefore, alfalfa belongs to the 2006 crop year technically even though 2005 was the first year of its commercial planting. Impacts that resulted from herbicide-resistant alfalfa will be reported in our next year's report.

The rapid and widespread adoption of herbicide-resistant crops in 2005, similar to other years since 1996, is mainly due to enhanced simplicity and flexibility of weed management in these crops. Following is an update on the economic, agronomic, and environmental impact of herbicide-resistant crops planted in 2005.

References

Wilkins, D. 2006. Roundup Ready alfalfa touted. Available at http://www.agbios.com/main.php?action=ShowNewsItem&id=7353

Berg, L. 2005. Weed-free alfalfa. Available at http://farmindustrynews.com/mag/farming weedfree_ alfalfa/

3. Canola

North Dakota continued to remain the dominant canola producing state in the United States in 2005, planting approximately 92% of the national canola acreage. Seven other states, Idaho, Michigan, Minnesota, Montana, Oklahoma, Oregon, and Washington, together, planted roughly 85,000 acres of canola in 2005 (National Agricultural Statistics Service: Acreage). Minnesota and Montana accounted for about 5% and 2%, respectively, of the total planted acreage in 2005.

Unlike 2003 and 2004, the years during which North Dakota's canola acreage slid from its 2001/2002 high of 1.3 million acres to 0.97 and 0.78 million acres, respectively, planted acreage increased by 33% in 2005 compared to the year before (Table 3.1). The record high canola yield obtained in 2004 was the main reason cited for the surge in planted acreage in 2005 (Coleman 2006). In Minnesota, on the other hand, planted acreage has been on a rapid decline since 2001, a year during which Minnesota growers planted 48% fewer acres to canola compared to 2000. Lower production costs and simplified weed management associated with glyphosate-resistant soybean have become more appealing to Minnesota growers, which led them to plant canola acres to soybean (Jenks 2006).

The adoption of biotechnology-derived herbicide-resistant canola increased dramatically in North Dakota in 2005. North Dakota canola growers planted 98% of the total acreage or 74% more acres to herbicide-resistant varieties in 2005 compared with 2004 (Coleman 2006; Jenks 2006; Tables 3.2 and 3.3). Increased adoption of biotechnology-derived canola in 2005 is attributed to the surging popularity of herbicide-resistant varieties and also overall increase in planted canola acreage (33%). Adoption of herbicide-resistant canola in Minnesota, the state for which impacts were calculated for the first time in this report, was 75% of the total planted acreage.

Averaged across the country, biotechnology-derived herbicide-resistant canola was planted on 93% of the total acreage in 2005. Of the total national acreage, glyphosate-resistant canola was planted on 62% of the area whereas glufosinate-resistant canola was planted on 31% of the acreage.

Similar to years before, American canola growers planted both glyphosate-resistant and glufosinate-resistant varieties in 2005 (Table 3.2). Acreage planted to glyphosate-resistant (Roundup Ready) canola varieties in North Dakota increased from 50% in 2004 to 65% in 2005, while plantings of glufosinate-resistant (Liberty Link) canola increased from 25% in 2004 to 33% (Table 3.3). On a percent basis, glufosinate-resistant canola was planted on more acres compared to glyphosate-resistant canola in North Dakota in 2005. The steady increase in the market share of glufosinate-resistant canola has been a trend since 2002 and was attributed to the availability of the trait in high yielding varieties, awareness and increased knowledge about the Liberty Link trait, and also due to a greater choice of varieties (Jenks 2006). Minnesota growers planted 50 and 25% of the total canola acreage to glyphosate- and glufosinate varieties, respectively.

Both glyphosate and glufosinate provided viable weed management options to canola growers due to their broad-spectrum of activity, convenient postemergence-based programs, and economic control of problem weeds. In addition to the reasons mentioned above, canola growers have planted biotechnology-derived herbicide-resistant varieties to control difficult weeds such as kochia, Canada thistle, wild buckwheat, wild oat, and yellow foxtail and seed contaminants such as wild mustard that may cause price discounts or rejection in the market.

A comparison of weed control programs in conventional, glyphosate-resistant, and glufosinate-resistant canola is presented in Table 3.4. Weed management programs and costs were assumed to be similar for both North Dakota and Minnesota (Jenks 2006).

On average, a typical weed management program in conventional canola (that could provide control comparable to the program in herbicide-resistant canola) cost about $39 per acre in 2005. In contrast, weed management costs in glyphosate-resistant and glufosinate-resistant canola, inclusive of technology fee/seed premium, were about $24 and $28 per acre, respectively. Growers of glyphosate-resistant and glufosinate-resistant canola, therefore, reduced their weed management costs by 62 and 28%, respectively, compared to growers of conventional canola in 2005. Weed management costs in herbicide-resistant canola included costs associated with the herbicide use, herbicide application, seed premium (for both varieties), and technology fee (for glyphosate-resistant canola only).

Impacts due to the planting of herbicide-resistant canola in North Dakota and Minnesota are presented in Table 3.5. Overall, canola growers saved $14.4 million on weed management costs using herbicide-resistant varieties in 2005. Similar to previous years, growers were also able to reduce the herbicide use in biotechnology-derived canola. Use of herbicide active ingredients per acre was 0.63 and 0.7 lb lower in glyphosate-resistant and glufosinate-resistant canola, respectively, compared to conventional canola (Table 3.4). Across the 2 states for which impacts were analyzed, this represented a reduction of 0.69 million pounds in herbicide use in 2005.

Planting of biotechnology-derived canola varieties decreased the weed management costs across the United States by 82% in 2005 compared with 2004. Additionally, pesticide use in canola was further reduced by 64% in 2005 (compared with 2004) due to the planting of biotechnology-derived varieties. Economic impacts were higher in North Dakota in 2005 due to an overall increase in planted canola acreage and also due to 74% increase in the adoption of biotechnology-derived herbicide-resistant varieties.

Table 3.1. Canola production in the top producing states

Year	Acres planted[1]		Production[2]		Value[3]	
	ND	MN	ND	MN	ND	MN
	000A		Million lb		Million $	
1987	0	---	0	---	---	---
1992	16	---	22	---	---	---
1997	376	110	427	147	---	---
1998	800	210	1147	290	117	---
1999	855	105	1085	130	81	---
2000	1270	140	1650	185	108	---
2001	1300	80	1799	89	158	7
2002	1300	80	1403	45	149	5
2003	970	57	1354	102	143	10
2004	780	35	1223	48	131	5
2005	1,040[4]	55	1462[5]	31	137	3

[1]Source: National Agricultural Statistics Service. 2005 Acreage
[2]Source: National Agricultural Statistics Service. 2005 Crop Production
[3]Source: National Agricultural Statistics Service. 2005 Crop Value
[4,5]Source: National Agricultural Statistics Service. Crop production 2005 summary.

Table 3.2. Adoption of biotechnology-derived herbicide-resistant (HR) canola in North Dakota[1,2] and Minnesota[2] in 2005[1]

State	Planted canola acreage	Total HR canola	Glyphosate-resistant[3] canola	Glufosinate-resistant[4] canola	HR canola acreage
	000A	---------------------Percent adoption		--------------------	000A
North Dakota	1040	98	65	33	1019
Minnesota	55	75	50	25	41
US Total/Average	**1135**	**93**	**62**	**31**	**1060**

[1]Source: Jenks 2006
[2]Source: Coleman 2006
[3]Roundup Ready
[4]Liberty Link

Table 3.3. Adoption trends for biotechnology-derived herbicide-resistant (HR) canola in North Dakota[1]

Year	Total HR canola	Glyphosate-resistant[2] canola	Glufosinate-resistant[3] canola	HR canola acreage
	---------------------Percent adoption ----------------------			000A
1999	25	24	1	214
2000	50	48	2	635
2001	70	67	3	910
2002	70	56	14	910
2003	75	55	20	728
2004	75	50	25	585
2005	98	65	33	1019

[1]Source: Coleman 2005; Jenks 2003; Jenks 2005; Coleman 2006; Jenks 2006
[2]Roundup Ready
[3]Liberty Link

Table 3.4. Comparison of weed management costs in various canola systems in 2005[1]

Conventional canola[2]			
Herbicides	**$/lb ai/A**	**Lb ai/A**	**$[3]/A**
Ethalfluralin (PRE) fb[4]	$8.78	0.94	$8.27
Quizalofop (POST)+	$145.54	0.056	$8.15
Clopyralid (POST)	$160.00	0.09	$14.40
Total		1.09	$30.82
Application cost (2 applications)			$8.00
Total weed management costs in conventional canola			$38.82
Glyphosate-resistant canola			
Seed premium			$5.00
Technology Fee plus 1 pint or 0.38 lb ae/A or 0.46 lb ai glyphosate (Roundup WeatherMax formulation)			$15.00
Application cost (1 application)			$4.00
Total cost			$24.00
Glufosinate-resistant canola			
Seed Premium			$5.00
Technology fee			$0.00
0.37 lb ai/A glufosinate ($15.29) + 0.023 lb ai/A quizalofop ($3.40)			$18.69
Application cost (1 application)			$4.00
Total cost			$27.69

[1]Sources: Brian Jenks of North Dakota State University for information on weed management programs and seed costs; Barry Coleman of Northern Canola Growers Association for technology fee and seed premium cost information
[2]For the purpose of this analysis, a single program is selected, as above, from several suggested alternative programs
[3]Herbicide costs were calculated from the 2005 North Dakota Herbicide Compendium
[4]Followed by

Table 3.5. Impacts of herbicide-resistant canola on US agriculture in 2005[1]

State	Herbicide-resistance trait	Planted acreage	Reduction in weed management costs		Reduction in herbicide use	
		000A	$/A	Million $	Lb/A	000 lb
ND	RR[2]	676	14.82	10.02	0.63	426
ND	LL[3]	343	11.13	3.82	0.70	240
Impacts due to herbicide-resistant canola in North Dakota				**13.84**		**666**
MN	RR	27.5	14.82	0.41	0.63	17.3
MN	LL	13.8	11.13	0.15	0.70	9.7
Impacts due to herbicide-resistant canola in Minnesota				**0.56**		**27**
Impacts due to herbicide-resistant canola in the United States				**14.4**		**693**

[1]Based on Tables 3.2 and 3.4
[2]Roundup Ready
[3]Liberty Link

References

2005 North Dakota Herbicide compendium. Available through the North Dakota State University Agricultural Communications Center.

Coleman, B. Northern Canola Growers Association. Personal communication. 2005 and 2006.

Jenks, B. North Dakota State University. Personal communication. 2005 and 2006.

National Agricultural Statistics Service. Acreage. Multiple year summaries. Available at http://www.usda.gov/nass.

National Agricultural Statistics Service. Crop Production. Multiple year summaries. Available at http://www.usda.gov/nass.

National Agricultural Statistics Service. Crop Values. Multiple year summaries. Available at http://www.usda.gov/nass.

National Agricultural Statistics Service. Crop production 2005 summary: Canola: Area Planted, Harvested, Yield, and Production by State and United States, 2003-2005. Available at http://www.usda.gov/nass.

4. Corn

American corn growers planted two biotechnology-derived herbicide-resistant cultivars in 2005, as in 2004 and 2003. They were glyphosate-resistant (trade name: Roundup Ready corn and Roundup Ready corn 2) and glufosinate-resistant (trade name: Liberty Link) corn. Together, the above two varieties were planted on 35% of the total corn acreage of the United States in 2005 (Table 4.1). South Dakota ranked first in the adoption of herbicide-resistant hybrids (85%) in 2005 followed by Texas (79%), Utah (75%) and Wyoming (75%) (Table 4.1). Planted acreage, on the other hand, was greatest in South Dakota followed by the major producing states in the Corn Belt such as Minnesota and Indiana.

Acreage planted to biotechnology-derived herbicide-resistant varieties increased by 67% in 2005 (27.93 million acres) compared with 2004 (16.7 million acres). Reasons for this dramatic surge in adoption include increased availability of the trait in hybrids suited to various geographic locations and the resolution of trade restrictions in export markets. In July 2004, the European Commission approved the import, processing, and use in animal feed of glyphosate-resistant corn (NK 603) in the European Union (EU). In October of the same year, the EU authorized the use of NK 603 as a single trait in food ingredients and products. Prior to this approval, the NK 603 or Roundup Ready Corn 2 was marketed under the Market Choices Certification Mark (MCCM). The MCCM identifies hybrids that are fully approved for food and feed use in the United States and Japan but not in the EU. The EU approval of NK 603 allowed for discontinued use of MCCM in single trait hybrids. As a result, adoption increased in most states including the midwestern states of the United States. Adoption of glyphosate-resistant corn is expected to further increase in the coming years with the availability of YieldGard Plus with Roundup Ready 2 Corn technology. YieldGard Plus with Roundup Ready 2 Corn technology, a triple trait/stacked product, was available in limited quantities in 2005.

Between the two biotechnology-derived herbicide-resistant varieties in the marketplace, glyphosate-resistant corn was the dominant cultivar in 2005, with about 31% adoption. Glufosinate-resistant corn was planted on about 4% of the 2005's planted corn acreage. Adoption of glufosinate-resistant corn varied widely among various regions and is generally low due to poor variety selection, non-availability of the trait in better-performing varieties, high price differential between glufosinate and glyphosate, ineffectiveness of glufosinate in controlling specific weeds in corn production such as nutsedge, pigweeds, and certain grasses, and the greater ability of glyphosate in controlling bigger weeds compared to glufosinate.

The niche for herbicide-resistant corn in 2005, as in previous years, was in the control of specific difficult to control weeds such as Johnsongrass, Bermudagrass, crabgrass, burcucumber, bindweed, and herbicide-resistant weeds such as kochia and pigweed for which conventional weed control programs have weaknesses. Besides being cost-effective (Table 4.2), weed management programs in herbicide-resistant corn enhanced flexibility in timing herbicide applications because glyphosate and glufosinate can be applied at later crop growth stages.

A survey of Crop Specialists (names listed in Reference section) in 2004 and 2005 suggested two major options for weed management in biotechnology-derived corn. The first and most widely used option is the use of half rate of a preemergence herbicide followed by either glyphosate or glufosinate as postemergence. The second approach involves a total postemergence-based program with either one or two applications of glyphosate or glufosinate or tankmix applications of glyphosate or glufosinate with atrazine.

Weed control strategies in biotechnology-derived herbicide-resistant corn, unlike soybean, necessitate the use of preemergence residual herbicides in addition to postemergence applications of glyphosate/glufosinate. Residual herbicide applications are needed in corn due to its earlier time of planting and its greater susceptibility to early season weed competition compared with soybean. As a result, preemergence residual herbicides (at half-rates) have become the basis of weed management programs in biotechnology-derived corn.

Comparative weed management programs and costs associated with glyphosate-resistant, glufosinate-resistant, and conventional corn are presented in Table 4.2. Weed management costs in 2005 were 25% and 28% lower in glyphosate-resistant and glufosinate-resistant corn, respectively, compared to conventional corn. Typical weed management program in conventional corn included premix applications of metolachlor + atrazine (preemergence) followed by a post-emergence application of mesotrione plus a premix of nicosulfuron + rimsulfuron. Substitution of the above program with half rate of preemergence applications of metolachlor + atrazine applications followed by glyphosate or glufosinate have led to reduction in herbicide use of 0.73 and 1.23 lb ai/acre, respectively.

Overall, biotechnology-derived glyphosate- and glufosinate-resistant corn reduced the herbicide use in corn by 21.8 million pounds (18.3 and 3.5 million pounds, respectively) in 2005 (Tables 4.3, 4.4, and 4.5). Furthermore, herbicide substitutions facilitated by the use of both glyphosate-resistant and glufosinate-resistant corn have resulted in grower cost savings of $269 million, due to lower costs associated with weed management programs in herbicide-resistant corn.

Net returns were improved by $138.7 million and pesticide use was reduced by 18.5 million pounds due to the planting of herbicide-resistant corn varieties in 2004. Based on the above, grower returns were 94% higher and pesticide use was 18% lower in 2005, compared with 2004, due to a significant increase (67%) in the adoption of herbicide-resistant corn varieties in 2005.

Similar to years since the first commercial use of herbicide-resistant corn, no-till corn acreage has increased significantly in 2004 (the recent year for which the survey information is available) also. No-till corn acres increased by 20% in 2004, 14% in 2002, and 9% in 2000 (based on the data from Conservation Technology Information Center's website; Table 4.6). The positive impacts from no-till production (such as reduced fuel use, soil erosion, runoff of pesticides and water, global warming potential, and greenhouse gas emissions and improved wild life habitat) will only increase as the adoption of herbicide-resistant crops continue to increase.

Table 4.1. Adoption of biotechnology-derived herbicide-resistant (HR) corn in the United States in 2005

State	Total corn acres planted[1]	Adoption of RR[2] corn	RR corn acreage	Adoption of LL[3] corn	LL corn acreage	Total adoption of HR corn	Total HR corn acreage	Source
	000A	%	000A	%	000A	%	000A	RR/LL
AL	200	49	98	6	12	55	110	Doane/Patterson
AZ	50	10	5	1	0.5	11	6	Doane/Clay
AR	240	47	113	1	2.4	48	115	Doane/Smith
CA	570	59	336	1	6	60	342	Doane/Lanini
CO	1,100	61	671	2	22	63	693	Doane/[4]
DE	160	32	51	3	5	35	56	Doane/VanGessel
GA	270	47	127	3	8	50	135	Doane/Prostko
ID	235	64	150	1	2	65	152	Doane/Morishita
IL	12,100	10	1210	1	121	11	1331	Doane/Hager
IN	5,900	14	826	1	59	15	885	Doane/NASS
IA	12,800	23	2944	5	640	28	3584	Doane/Hartzler
KS	3,650	53	1934	2	73	55	2007	Doane//Peterson
KY	1,250	37	463	1.5	19	39	482	Doane/Ewing
LA	340	59	201	1	3	60	204	Doane/Lanclos
MA	20	24	5	2	0.4	26	5	Barlow/Barlow
MD	470	41	193	2	9	43	202	Doane/[4]
MI	2,250	22	495	2	45	24	540	Doane/Sprague
MN	7,300	46	3358	5	365	51	3723	Doane/Gunsolus
MS	380	42	160	1	4	43	164	Doane/Shaw
MO	3,100	24	744	3	93	27	837	NASS/Bradley
NC	750	36	270	15	113	51	383	Doane/York
ND	1,410	63	888	5	71	68	959	Doane/[4]
NE	8,500	32	2720	1	85	33	2805	NASS/Martin
NJ	80	20	16	3	2	23	18	VanGessel/VanGessel
NM	140	45	63	4	6	49	69	Doane/McWilliams
NY	990	22	218	1	10	23	228	Doane/Hahn
OH	3,450	13	449	0.5	17	14	466	Doane/Loux
OK	290	36	104	30	87	66	191	Doane/Medlin
PA	1,350	18	243	3	41	21	284	Doane/Curran
SC	300	64	192	2	6	66	198	Doane/Main
SD	4,450	70	3115	15	668	85	3783	Doane/Moechnig
TN	650	15	98	0.25	2	15	100	Doane/Hayes
TX	2,050	74	1517	5	103	79	1620	Doane/Baumann
UT	55	75	41	0	0	75	41	Griggs/Griggs
VA	490	16	78	2	10	18	88	Doane/Hagood
VT	95	20	19	2	2	22	21	Giguere/Giguere
WV	45	34	15	3	1	37	16	Chandran/Chandran
WI	3,800	24	912	3	114	27	1026	Doane/Boerboom
WY	80	75	60	0	0	75	60	Doane/Miller
Total/Average	**81,130**	**31**	**25,102**	**4**	**2,827**	**35**	**27,929**	
US Total/Average	**81,759**	**31**		**4**		**35**		

[1]Source: National Agricultural Statistics Service. 2005 Acreage
[2]RR = Glyphosate-resistant or Roundup Ready corn; [3]LL = Glufosinate-resistant or Liberty Link corn; [4]assumed based on adoption in the neighboring states

Table 4.2. Herbicide substitution analysis[1] in biotechnology-derived herbicide-resistant (HR) corn

Program	Herbicide rate	Herbicide costs
	lb ai/A	$/A
Conventional corn		
Premix of Metolachlor + Atrazine[2] as PRE followed by	3.16	23.59
Mesotrione[3] + premix of Nicosulfuron + Rimsulfuron[4] as POST (both at half rates, 0.05 + 0.02 lb ai/A, respectively)	0.07	14.03
Total for conventional program	**3.23**	**37.62**
Glyphosate-resistant (Roundup Ready or RR) corn		
Metolachlor + Atrazine[2] as PRE followed by	1.58	11.80
Glyphosate[5] as POST	0.92	9.33
Seed premium costs/technology fee		7.00
Total for RR program	**2.50**	**28.13**
Glufosinate-resistant (Liberty Link or LL) corn		
Metolachlor/atrazine[2] as PRE followed by	1.58	11.80
Glufosinate[6] as POST	0.42	15.10
Seed premium costs/technology fee		0
Total for LL program	**2.00**	**26.90**
Difference		
	-0.73	**-9.49**
	-1.23	**-10.72**

[1]Based on the survey of Weed Specialists (listed in References section) in 2005 and 2006
[2]Trade name: Bicep II Magnum
[3]Trade name: Callisto
[4]Trade name: Steadfast
[5]Trade name: Roundup
[6]Trade name: Liberty

Table 4.3. Impacts of herbicide-resistant Roundup Ready (RR) corn in 2005

State	Total corn acres planted	RR corn acreage	Impacts due to RR corn: Reduction in herbicide use[1]	Reduction in weed management costs[2]
	000A	000A	000 lb ai	000$
AL	200	98	72	930
AZ	50	5	4	47
AR	240	113	83	1072
CA	540	336	245	3189
CO	1,100	671	490	6368
DE	160	51	37	484
GA	270	127	93	1205
ID	235	150	110	1423
IL	12,100	1210	883	11483
IN	5,900	826	603	7838
IA	12,800	2944	2149	27939
KS	3,650	1934	1412	18354
KY	1,250	463	338	4394
LA	340	201	147	1907
MA	20	5	4	47
MD	470	193	141	1832
MI	2,250	495	361	4698
MN	7,300	3358	2451	31867
MS	380	160	117	1518
MO	3,100	744	543	7061
NC	750	270	197	2562
ND	1,410	888	648	8427
NE	8,500	2720	1986	25813
NJ	80	16	12	152
NM	140	63	46	598
NY	990	218	159	2069
OH	3,450	449	328	4261
OK	290	104	76	987
PA	1,350	243	177	2306
SC	300	192	140	1822
SD	4,450	3115	2274	29561
TN	650	98	72	930
TX	2,050	1517	1107	14396
UT	55	41	30	389
VA	490	78	57	740
VT	95	19	14	180
WV	45	15	11	142
WI	3,800	912	666	8655
WY	80	60	44	569
Total	**81,130**	**25,102**	**18,327**	**238,215**

[1]Calculated at 0.73 lb ai/A based on Table 4.2; [2]Calculated at $9.49/A based on Table 4.2

Table 4.4. Impacts of herbicide-resistant Liberty Link (LL) corn in 2005

State	Total corn acres planted	LL corn acreage	Impacts due to LL corn: Reduction in herbicide use[1]	Impacts due to LL corn: Reduction in weed management costs[2]
	000A	000A	000 lb ai	000$
AL	200	12	15	129
AZ	50	0.5	1	5
AR	240	2.4	3	26
CA	570	6	7	64
CO	1,100	22	27	236
DE	160	5	6	54
GA	270	8	10	86
ID	235	2	2	21
IL	12,100	121	149	1297
IN	5,900	59	73	632
IA	12,800	640	787	6861
KS	3,650	73	90	783
KY	1,250	19	23	204
LA	340	3	4	32
MA	20	0.4	1	4
MD	470	9	11	96
MI	2,250	45	55	482
MN	7,300	365	449	3913
MS	380	4	5	43
MO	3,100	93	114	997
NC	750	113	140	1211
ND	1,410	71	87	761
NE	8,500	85	105	911
NJ	80	2	2	21
NM	140	6	7	64
NY	990	10	12	107
OH	3,450	17	21	182
OK	290	87	107	933
PA	1,350	41	50	440
SC	300	6	7	64
SD	4,450	668	822	7161
TN	650	2	2	21
TX	2,050	103	127	1104
UT	55	0	0	0
VA	490	10	12	107
VT	95	2	2	21
WV	45	1	1	11
WI	3,800	114	140	1222
WY	80	0	0	0
Total	**81,130**	**2,827**	**3,476**	**30,306**

[1]Calculated at 1.23 lb ai/A based on Table 4.2
[2]Calculated at $10.72/A based on Table 4.2

Table 4.5. Aggregate impacts of herbicide-resistant (HR) corn in 2005[1]

State	Total corn acres planted	HR corn acreage	Impacts due to HR corn: Reduction in herbicide use	Impacts due to HR corn: Reduction in weed management costs
	000A	000A	000 lb ai	000$
AL	200	110	87	1059
AZ	50	6	5	52
AR	240	115	86	1098
CA	570	342	252	3253
CO	1,100	693	517	6604
DE	160	56	43	538
GA	270	135	103	1291
ID	235	152	112	1444
IL	12,100	1331	1032	12780
IN	5,900	885	676	8470
IA	12,800	3584	2936	34800
KS	3,650	2007	1502	19137
KY	1,250	482	361	4598
LA	340	204	151	1939
MA	20	5	5	51
MD	470	202	152	1928
MI	2,250	540	416	5180
MN	7,300	3723	2900	35780
MS	380	164	122	1561
MO	3,100	837	657	8058
NC	750	383	337	3773
ND	1,410	959	735	9188
NE	8,500	2805	2091	26724
NJ	80	18	14	173
NM	140	69	53	662
NY	990	228	171	2176
OH	3,450	466	349	4443
OK	290	191	183	1920
PA	1,350	284	227	2746
SC	300	198	147	1886
SD	4,450	3783	3096	36722
TN	650	100	74	951
TX	2,050	1620	1234	15500
UT	55	41	30	389
VA	490	88	69	847
VT	95	21	16	201
WV	45	16	12	153
WI	3,800	1026	806	9877
WY	80	60	44	569
Total/Average	**81,130**	**27,929**	**21,803**	**268,521**

[1]Includes impacts from glyphosate-resistant and glufosinate-resistant corn from Tables 4.3 and 4.4.

Table 4.6. Impact of biotechnology-derived herbicide-resistant varieties on no-till corn acreage in the United States

Year	No-till acreage (Million acres)	No-till acreage as a % of total	% Increase in no-till acreage based on 1996
1996	13.17	16.8	-
1997	13.7	17.3	4
1998	13.2	16.4	0.3
2000	14.35	17.9	9
2002	15.0	19.1	14
2004	15.82	19.7	20

Source: Conservation Technology Information Center.

References

Barlow, M. Crop Production Services. Personal communication. 2006.

Bauman, P. Texas A and M University. Personal communication. 2006.

Boerboom, C. University of Wisconsin. Personal communication. 2006.

Bradley, K. University of Missouri. Personal communication. 2006.

Chandran, R. West Virginia University. Personal communication. 2006.

Clay, P. University of Arizona. Personal communication. 2006.

Conservation Technology Information Center. Available at http://www.ctic.purdue.edu/Core4/Core4Main.html.

Curran, W. Pennsylvania State University. Personal communication. 2006.

Doane's Marketing Research, Inc. (DMR). 2005 Corn Trait Data.

Ewing, J. University of Kentucky. Personal communication. 2006.

Giguere, C. Vermont Agency of Agriculture. Personal communication. 2006.

Griggs, T. Utah State University. Personal communication. 2006.

Gunsolus, J. University of Minnesota. Personal communication. 2006.

Hager, A. University of Illinois. Personal communication. 2006.

Hagood, S. Virginia Polytechnic University. Personal communication. 2006.

Hahn, R. Cornell University. Personal communication. 2006.

Hartzler, R. Iowa State University. Personal communication. 2006.

Hayes, R. University of Tennessee. Personal communication. 2006.

Lanclos, D. Louisiana State University. Personal communication. 2006.

Lanini, T. University of California at Davis. Personal communication. 2006.

Loux, M. Ohio State University. Personal communication. 2006.

Main, C. Clemson University. Personal communication. 2006

McWilliams, D. New Mexico State University. Personal communication. 2006.

Medlin, C. Oklahoma State University. Personal communication. 2006.

Miller, S. University of Wyoming. Personal communication. 2006.

Moechnig, M. South Dakota State University. Personal communication. 2006.

Morishita, D. University of Idaho. Personal communication. 2006.

National Agricultural Statistics Service. 2005 Acreage. Available at http://www.usda.gov/nass.

Martin, A. University of Nebraska. Personal communication. 2006.

Patterson, M. Auburn University. Personal communication. 2006.

Peterson, D. Kansas State University. Personal communication. 2006.

Prostko, E. University of Georgia. Personal communication. 2006.

Shaw, A. Mississippi State University. Personal communication. 2006.

Smith, K. University of Arkansas. Personal Communication. 2006.

Sprague, C. Michigan State University. Personal communication. 2006.

VanGessel, M. University of Delaware. Personal communication. 2006.

York, A. North Carolina State University. Personal communication. 2006.

5. Cotton

American growers planted 13.9 million acres of cotton in 2005. Of these, about 11.1 million acres or 80% were planted to biotechnology-derived herbicide-resistant (HR) cotton varieties. Number of acres planted to herbicide-resistant varieties increased by 3% in 2005 compared with 2004. Similar to 2004, adoption of biotechnology-derived herbicide-resistant varieties exceeded 90% in all the cotton producing states of the United States except Arizona, California, New Mexico, and Texas (Table 5.1). Planted HR cotton acreage in 2005 was highest in Texas (3.62 million acres) followed by Georgia (1.19 million acres), Mississippi (1.12 million acres), and Arkansas (1.04 million acres).

Two biotechnology-derived herbicide-resistant cotton cultivars were planted in 2005. They include glyphosate-resistant (Roundup Ready or RR) and glufosinate-resistant (Liberty Link or LL) cotton. Production of bromoxynil-resistant (BXN) cotton, an herbicide-resistant cotton application planted since 1995, ceased in 2005. Bromoxynil-resistant cotton was withdrawn from the market due to its lower adoption that resulted from the non-availability of stacked varieties, lack of broad-spectrum weed control with bromoxynil, and restrictions placed on the use of bromoxynil by the Environmental Protection Agency.

Glyphosate-resistant cotton had the lion share of 78% while glufosinate-resistant cotton accounted for only 2% of the total planted herbicide-resistant cotton acreage in 2005 (Table 5.1). Whereas glyphosate-resistant cotton was planted on 10.8 million acres, glufosinate-resistant cotton was planted on only 0.33 million acres in 2005 (Table 5.1). Planted acreage of glufosinate-resistant cotton was highest in Texas (5% or 0.3 million acres) in 2005. In general, adoption of glufosinate-resistant cotton was low and was only significant (around 2000 acres or higher) in Arkansas, California, Georgia, Mississippi, Tennessee, and Texas. This is mainly due to low seed supplies during the second year of its commercial availability.

While both glyphosate and glufosinate are post-emergence, non-residual, non-selective, over-the-top herbicides, there are several contrasts between glyphosate and glufosinate based weed management systems. Whereas glyphosate can be applied over-the-top (broadcast) only up to 4-5 leaf stage of the first generation glyphosate-resistant cotton (precision post-direct equipment must be used after this stage), glufosinate has a larger over-the-top application window and can be applied up to 70 days prior to harvest (Lemon et al. 2004). Hence, timing of herbicide applications is more flexible with glufosinate-resistant cotton (Culpepper 2003).

Unlike glyphosate, glufosinate is not effective against nutsedge, grasses, and pigweeds. Control of morning glory, smartweed, and hemp sesbania, on the other hand, is superior with glufosinate compared to glyphosate. Another major difference between the two systems is that glyphosate is used as repeated and as-needed applications until lay-by while glufosinate is used in more of a pre-planned, traditional type program. However, this has changed since 2006 due to the availability of Roundup Ready Flex cotton (discussed below). Regardless the differences, the availability of glyphosate and glufosinate-resistant cotton systems serve as valuable tools in managing weed resistance and population shifts due to their diverse mechanisms of action.

The second generation glyphosate-resistant cotton, referred to as Roundup Ready Flex cotton, was approved by the regulatory agencies in the United States in 2005 and was planted on growers fields in 2006. Unlike the first generation of Roundup Ready cotton, which can tolerate glyphosate applications only up to the 4th leaf stage, Roundup Ready Flex cotton possesses both vegetative and reproductive tolerance to glyphosate and can be applied over-the-top from cotton emergence through seven days prior to harvest without any concern for crop injury. It is anticipated that Roundup Ready Flex cotton will re-define the cotton weed management in the United States because of the enhanced crop safety, flexibility, convenience, weed control efficacy, and production efficiency afforded by it (Murdock 2006).

A survey was conducted in 2005 and again in 2006 to identify the herbicide programs that were replaced in conventional cotton with glyphosate and glufosinate-based weed management programs. The names of the cotton Weed Specialists that specified the management programs were listed in the References section. The most widely used weed management program in conventional cotton along with herbicide use rate and cost for each of the states is detailed in Table 5.2. Weed management program costs were calculated based on the herbicide prices compiled by Ferrell and MacDonald (2005).

Representative weed management programs in RR and LL cotton are presented for various states in Table 5.3. The impact of biotechnology-derived varieties on herbicide use and weed management costs was calculated based on the information presented in Tables 5.2 and 5.3. Calculations related to impacts on number of herbicide applications, tillage, and hand weeding operations were based on the National Center's 2002 report.

Biotechnology-derived herbicide-resistant varieties have led to a new era for weed management in cotton. The primary advantage of herbicide-resistant cotton for growers was the increased ease in applying the postemergence over-the-top herbicides with excellent crop safety. Production costs have also decreased as growers have made fewer trips across fields applying herbicides, made fewer cultivation trips, and performed fewer handweeding operations. Thus, cotton growers have adopted the biotechnology-derived varieties in 2005 as a way to reduce production costs, as in the years before.

Similar to 2004, significant reductions have been observed in overall herbicide use and herbicide costs (Tables 5.4 and 5.5); number of herbicide applications; tillage; and handweeding operations in 2005 (Table 5.6). Though seed premium and technology fee costs increased crop production expenses (Table 5.7), savings from other weed management costs have more than offset these increased costs. The overall impact of herbicide-resistant cotton on US agriculture has been a reduction in crop production costs of $39 million (Table 5.8) and pesticide use of 18 million pounds (Table 5.5).

A major happening in the 2005 crop season was the significant increase in technology fee costs for glyphosate-resistant cotton. Technology fee costs for glyphosate-resistant cotton doubled in 2005 ($28) compared to 2004 ($14). Increase in seed premium/technology fee costs for glufosinate-resistant cotton, on the other hand, was 7% in 2005. This lead to an overall increase in crop production costs for biotechnology-derived herbicide-resistant cotton producers in the United States. As a result, net returns were significantly lower in 2005 compared with 2004 ($264 million). However, in spite of increased technology fee costs, American cotton growers were able to increase their returns by $39 million in 2005. Herbicide use, on the other hand, continued to decrease, by an additional 27% in 2005 compared to 2004, due to expanded acreage of biotechnology-derived herbicide-resistant cotton and changes in weed management programs in 2005.

Commercial planting of Roundup Ready Flex cotton took place in the United States in 2006. Research findings from extensive grower trials throughout the Cotton Belt in 2005 indicate that Roundup Ready Flex cotton enhanced the flexibility in timing herbicide applications, facilitated co-applications of herbicides, insecticides and plant growth regulators, reduced the reliance on specialized equipment used for post-directed sprays, and led to significant time savings (Monsanto 2006).

Roundup Ready Flex cotton received import approval in key markets such as Canada, Japan, and Mexico in February 2006 (Delta Farm Press 2006). It is anticipated that approvals in crucial export markets together with availability of the Roundup Ready Flex/Bollgard II stacked product will further enhance the adoption of herbicide-resistant cotton in the United States. Roundup Ready Flex cotton offered for planting during the 2006 crop season is a single-trait product. Efforts are in progress to market Roundup Ready Flex cotton stacked with Bollgard II trait to expand the protection against other key cotton pest problems. The U.S. Environmental Protection Agency's granting of unconditional registration for Bollgard II insect-protected cotton technology in September 2006 will further enhance the adoption of biotechnology-derived traits in cotton production in the United States.

A major impact of biotechnology-derived herbicide-resistant crops in the United States has been increase in the adoption of no-till production practices. No-till crop acres rose significantly in soybean, corn, and cotton; however, percent increase in no-till acreage has been higher in cotton than any other crop. For example, no-till cotton acres were increased by 371% in 2004, the latest year for which the estimates are available, compared with 1996 (Table 5.9), while increases were 20 and 64% in corn and soybean, respectively. The above estimates are based on the information compiled by the Conservation Technology Information Center. A study conducted by Doane Marketing Research (2002) for the Cotton Foundation also indicated similar trends in no-till cotton acreage during the period from 1997 to 2002.

Several reasons have been cited for the dramatic increase in no-till cotton acreage. These include adoption of herbicide-resistant crops which enable the over the top herbicide applications, enhanced awareness in growers of the benefits of conservation tillage practices, increase in fuel prices, access to better no-till equipment, and availability of better herbicides to control weeds in no till fields. However, biotechnology-derived herbicide-resistant cotton is by far the leading reason for this increase in no-till production practices in cotton. In fact, 79% of the cotton growers surveyed by the Doane Marketing Research have responded that herbicide-resistant cotton has enabled them to successfully incorporate no-till production into their farming operations. The Doane study also indicated that conservation tillage practices, such as no-till, result in about $20 savings in fuel and labor per acre. Assuming that the entire no-till cotton acreage in 2004 (2.4 million acres) was planted to herbicide-resistant varieties, fuel and labor cost savings were estimated to be $48 million.

Table 5.1. Herbicide-resistant (HR) cotton adoption in the United States in 2005[1]

State	Planted cotton acreage[2]	RR[3] cotton adoption	LL[4] cotton adoption	Total HR cotton adoption	RR cotton acres	LL cotton acres	Total HR cotton acres
	000A	%	%	%	000A	000Acres	000A
AL	550	94.32	0	94.32	519	0	519
AZ	230	66.18	0.07	66.25	152	0.2	152
AR	1,050	98.01	1.27	99.28	1,029	13.3	1,042
CA	430	42.40	0.95	43.35	182	4.1	186
FL	86	90.93	0	90.93	78	0	78
GA	1,220	97.14	0.54	97.68	1,185	6.6	1,192
KS	74	95.82	0	95.82	71	0	71
LA	610	97.65	0.16	97.81	596	1	597
MS	1,210	96.15	1.14	97.29	1,163	13.8	1,177
MO	440	96.55	0.05	96.6	425	0.2	425
NM	56	71.93	0	71.93	40	0	40
NC	815	98.81	0.16	98.97	805	1.3	806
OK	255	95.14	0	95.14	243	0	243
SC	266	93.48	0.08	93.56	249	0.2	249
TN	640	98.74	0.80	99.54	632	5.1	637
TX	5900	56.51	4.86	61.4	3,334	286.7	3,621
VA	93	97.35	2.22	99.57	91	2.1	93
Total/ Average	**13,925**	**77.5**	**2.4**	**79.9**	**10,794**	**334.6**	**11,128**

[1]Source: Agricultural Marketing Service. Cotton Varieties Planted, United States, 2005 Crop
[2]Source: National Agricultural Statistics Service. 2005 Acreage
[3]RR = Biotechnology-derived glyphosate-resistant or Roundup Ready cotton
[4]LL = Biotechnology-derived glufosinate-resistant or Liberty Link cotton

Table 5.2. Typical weed management programs in various cotton growing states of the US in 2005 as suggested by University Weed Specialists across the Cotton Belt[1]

State	Standard weed management program[2] (lb ai/A)					Total ai used	Cost of herbicide program[3]
	PPI	PRE	POST	POST-DIR	Post-Dir/Layby	Lb ai/A	$/A
AL		Fluometuron (1.5)	Pyrithiobac (0.063)		Prometryn (0.5) + MSMA (2.0)	4.1	44.85
AZ	Pendimethalin (1.5)		Pyrithiobac (0.063) + MSMA (2.0)	Prometryn (0.5)	Diuron (1.3) + Carfentrazone (0.024)	5.4	57.44
AR	Pendimethalin (0.6)	Fluometuron (0.5)	Pyrithiobac (0.063)	MSMA (2.0)	Prometryn (1.0)	4.2	44.03
CA	Trifluralin (1.0)		Pyrithiobac (0.063) + Clethodim (0.09)	MSMA (2.0)	Prometryn (0.5) + MSMA (2.0)	5.7	53.70
FL	Pendimethalin (0.75)	Fluometuron (1.5)	Prometryn (0.75) + MSMA (2.0)			5.0	28.47
GA	Pendimethalin (0.75)	Fluometuron (1.0)	Pyrithiobac (0.063) + MSMA (0.75)		Diuron (1.0) + MSMA (2.0)	5.6	49.70
KS	Pendimethalin (1.0)	Fluometuron (1.0)	Clethodim (0.125)	Prometryn (0.75)	Diuron (1.0) + MSMA (2.0)	5.9	41.98
LA		Pendimethalin (0.75) + fluometuron (0.75)	Pyrithiobac (0.063)	Fluometuron (0.75) + MSMA (2.0)	Diuron (1.0)	5.3	51.20
MS	Pendimethalin (1.0)		Pyrithiobac (0.063)	Prometryn (0.5) fb[4] MSMA (2.0)	Diuron (1.0) + MSMA (1.5)	6.1	49.15
MO		Fluometuron (1.2)	Clethodim (0.09)	Fluometuron (1.0) + MSMA (1.5)	Diuron (1.0) + MSMA (1.5)	6.3	40.48
NM	Trifluralin (0.5)	Fluometuron (1.0)		Diuron (1.0) + MSMA (2.0)		4.5	22.87
NC	Pendimethalin (0.75)	Fluometuron (1.0)	Pyrithiobac (0.07)	Prometryn (0.75)	MSMA (2.0) + Prometryn (0.5)	5.1	53.18
OK	Pendimethalin (0.63)			Fluometuron (1.0) fb[3] prometryn (0.8)	Diuron (0.75)	3.2	20.79
SC	Pendimethalin (0.83)	Fluometuron (1.0)	Pyrithiobac (0.063)	Prometryn (1.0) + MSMA (2.0)		4.9	49.46
TN	Trifluralin (0.75)	Fluometuron (1.4)	Pyrithiobac (0.06) + Clethodim (0.125)	Diuron (1.0) + MSMA (2.0)		5.3	61.34
TX	Trifluralin (1.0)		Pyrithiobac (0.063) + MSMA (0.75)	Prometryn (1.5) + MSMA (1.0)		4.3	49.37
VA	Pendimethalin (0.63)	Fluometuron (1.0)		Prometryn (0.8)	Diuron (0.75)	3.2	20.79
Average						**4.95**	**43.60**

[1]Specialists that specified the weed management programs for their respective states are listed in the References section
[2]PPI = preplant incorporated; PRE = preemergence; POST = postemergence; POST-DIR = post-directed
[3]Weed management program costs were calculated based on Ferrell and McDonald's University of Florida's Approximate Herbicide Pricing – 2005
[4]fb=followed by

Table 5.3a. Typical weed management programs in biotechnology-derived glyphosate-resistant cotton as suggested by University Weed Specialists across the Cotton Belt [1]

Herbicide program	Herbicide rates (Lb ai/A)	Total (Lb ai/A)	Program costs ($/A)
1. Trifluralin preemergence followed by glyphosate[2] before 4th leaf followed by glyphosate + diuron as layby treatments	0.75 + 1.0 + 0.5 + 0.75	3.0	23.69
2. Three postemergence applications of glyphosate	1.0 + 1.0 + 1.0	3.0	30.42
3. Two postemergence applications of glyphosate followed by diuron + MSMA as layby treatments	1.0 + 0.5 + 1.0 + 2.0	4.5	26.88
4. Pendimethalin preemergence followed by 2 postemergence applications of glyphosate followed by carfentrazone + prometryn as layby treatments	0.75 + 0.75 + 0.75 + 0.024 + 0.5	2.8	31.97
5. Pendimethalin preemergence followed by postemergence applications of glyphosate + pyrithiobac followed by glyphosate + prometryn as POST-DIR treatments	0.75 + 0.75 + 0.048 + 0.5 + 0.5	2.55	38.16
6. Pendimethalin preemergence followed by 1 postemergence application of glyphosate + Dual II Magnum followed by glyphosate + Diuron as POST-DIR	0.75 + 0.75 + 0.95 + 0.75 + 0.75	3.95	36.2
7. Dual II Magnum preemergence followed by 1 postemergence application of glyphosate followed by glyphosate + Diuron as POST-DIR	0.95 + 0.75 + 0.75 + 0.75	3.2	31.47
Average		**3.3**	**31.26**

[1]Specialists that specified the weed management programs for their respective states are listed in the References section

[2]Roundup WeatherMax formulations used in the calculations

Table 5.3b. Typical weed management programs in biotechnology-derived glufosinate–resistant cotton as suggested by University Weed Specialists across the Cotton Belt [1]

Herbicide program	Herbicide rates (Lb ai/A)	Total (Lb ai/A)	Program costs ($/A)
1. Pendimethalin premergence followed by 2 postemergence applications of glufosinate (early to mid POST and late POST) followed diuron + MSMA as layby treatments	0.75 + 0.42 + 0.42 + 0.75 + 2.0	4.34	46.6
2. Pendimethalin premergence followed by 1 postemergence application of glufosinate (mid to late POST) followed by diuron + MSMA as layby treatments	0.75 + 0.42 0.75 + 2.0	3.92	31.5
3. Two postemergence applications of glufosinate (at 2-leaf followed by 5-6 leaf stages) followed by diuron + MSMA as layby treatments	0.42 + 0.42 + 0.75 + 2.0	3.59	41.87
4. Glufosinate at 2-leaf stage followed by glufosinate + metolachlor at 5-6 leaf stage followed by diuron + MSMA as layby treatments	0.42 + 0.21 + 0.95 + 0.75 + 2.0	4.33	46.82
5. Pendimethalin premergence followed by 2 postemergence applications of glufosinate (early to mid POST and late POST to layby)	0.75 + 0.42 + 0.42	1.59	34.93
6. Three glufosinate applications (early POST, mid POST, layby)	0.42 + 0.42 + 0.21	1.05	37.75
7. Pendimethalin + Diuron premergence followed by 1 postemergence application of glufosinate	1.0 + 0.75 + 0.42	2.17	26.4
Average		**3.0**	**37.98**

[1]Specialists that specified the weed management programs for their respective states are listed in the References section

Table 5.4a. Impacts of glyphosate-resistant (Roundup Ready/RR) cotton on herbicide use and weed management costs in 2005

State	Planted acreage	RR acres	Conventional program		Impacts on		Aggregate impacts on	
	000A	000A	Herbicide use (lb ai/A)	Program cost ($/A)	Herbicide use[1] (lb ai/A)	Costs[2] ($/A)	Herbicide use (000 lb)	Weed management costs (000$)
AL	550	519	4.1	44.85	-0.8	-13.59	-415	-7053
AZ	230	152	5.4	57.44	-2.1	-26.18	-319	-3979
AR	1,050	1,029	4.2	44.03	-0.9	-12.77	-926	-13140
CA	430	182	5.7	53.70	-2.4	-22.44	-437	-4084
FL	86	78	5.0	28.47	-1.7	2.79	-133	218
GA	1,220	1,185	5.6	49.70	-2.3	-18.44	-2726	-21851
KS	74	71	5.9	41.98	-2.6	-10.72	-185	-761
LA	610	596	5.3	51.20	-2.0	-19.94	-1192	-11884
MS	1,210	1,163	6.1	49.15	-2.8	-17.89	-3256	-20806
MO	440	425	6.3	40.48	-3.0	-9.22	-1275	-3919
NM	56	40	4.5	22.87	-1.2	8.39	-48	336
NC	815	805	5.1	53.18	-1.8	-21.92	-1449	-17646
OK	255	243	3.2	20.79	0.1	10.47	24	2544
SC	266	249	4.9	49.46	-1.6	-18.2	-398	-4532
TN	640	632	5.3	61.34	-2.0	-30.08	-1264	-19011
TX	5900	3,334	4.3	49.37	-1.0	-18.11	-3334	-60379
VA	93	91	3.2	20.79	0.1	10.47	9	953
US	**13,925**	**10,794**	**4.95**	**43.60**	**-1.6**	**-12.20**	**-17,324**	**-184,994**

[1]Average herbicide use in RR cotton in 2005 = 3.3 lb ai/A (from Table 5.3a)
[2]Average cost of weed management program in RR cotton in 2005 = $31.26/A (from Table 5.3a)

Table 5.4b. Impacts of glufosinate-resistant (Liberty Link/LL) cotton on herbicide use and weed management costs in 2005

State	Planted acreage	LL acres	Conventional program		Impacts on		Aggregate impacts on	
	000A	000A	Herbicide use (lb ai/A)	Program cost ($/A)	Herbicide use[1] (lb ai/A)	Costs[2] ($/A)	Herbicide use (000 lb)	Weed management costs (000$)
AL	550	0	4.1	44.85	-1.1	-6.87	0	0
AZ	230	0.2	5.4	57.44	-2.4	-19.46	-0.5	-3.9
AR	1,050	13.3	4.2	44.03	-1.2	-6.05	-16.0	-80.5
CA	430	4.1	5.7	53.70	-2.7	-15.72	-11.1	-64.5
FL	86	0	5.0	28.47	-2.0	9.51	0	0
GA	1,220	6.6	5.6	49.70	-2.6	-11.72	-17.2	-77.4
KS	74	0	5.9	41.98	-2.9	-4.00	0	0
LA	610	1	5.3	51.20	-2.3	-13.22	-2.3	-13.2
MS	1,210	13.8	6.1	49.15	-3.1	-11.17	-42.8	-154.1
MO	440	0.2	6.3	40.48	-3.3	-2.5	-0.7	-0.5
NM	56	0	4.5	22.87	-1.5	15.11	0	0
NC	815	1.3	5.1	53.18	-2.1	-15.2	-2.7	-19.8
OK	255	0	3.2	20.79	-0.2	17.19	0	0
SC	266	0.2	4.9	49.46	-1.9	-11.48	-0.4	-2.3
TN	640	5.1	5.3	61.34	-2.3	-23.36	-11.7	-119.1
TX	5900	286.7	4.3	49.37	-1.3	-11.39	-372.7	-3265.5
VA	93	2.1	3.2	20.79	-0.2	17.19	-0.4	-36.1
US	**13,925**	**334.6**	**4.95**	**43.60**	**-1.9**	**-5.48**	**-479**	**-3765**

[1]Average herbicide use in LL cotton in 2005 = 3.0 lb ai/A (Table 5.3b)
[2]Average cost of weed management program in LL cotton in 2005 = $37.98/A (Table 5.3b)

Table 5.5. Overall impact[1] of herbicide-resistant cotton on herbicide use and weed management costs in 2005

State	Total planted cotton acreage	Total HR cotton acreage	Impacts on	
	000A	000 A	**Herbicide use** 000 lb	**Weed management costs** 000 $
AL	550	519	-415	-7053
AZ	230	152	-320	-3983
AR	1,050	1,042	-942	-13221
CA	430	186	-448	-4149
FL	86	78	-133	218
GA	1,220	1,192	-2743	-21774
KS	74	71	-185	-761
LA	610	597	-1194	-11897
MS	1,210	1,177	-3299	-20960
MO	440	425	-1276	-3920
NM	56	40	-48	336
NC	815	806	-1452	-17666
OK	255	243	24	2544
SC	266	249	-398	-4534
TN	640	637	-1276	-19130
TX	5900	3,621	-3707	-63645
VA	93	93	9	989
US	**13,925**	**11,128**	**-17,803**	**-188,606**

[1]Includes the impacts of glyphosate-resistant (Roundup Ready) and glufosinate-resistant (Liberty Link) cotton

Table 5.6. Impact of herbicide-resistant (HR) cotton on other weed management costs in 2005

State	HR cotton adoption		Tillage		Herbicide application		Handweeding		
	%	000A	#/A[1]	000$[2]	Trips/A[3]	000$[4]	000A[5]	Hours/A[6]	000$[7]
AL	94	519	-2.0	-4671	0	0	39	-1.0	-383
AZ	66	152	-2.5	-1710	-1	-608	46	-4.0	-1805
AR	99	1,042	-1.0	-4689	-2	-8336	420	-2.0	-8240
CA	43	186	-2.5	-2093	-1	-744	323	-8.0	-25349
FL	91	78	-2.0	-702	0	0	0	0	0
GA	98	1,192	-1.0	-5364	-1	-4768	61	-2.5	-1496
KS	96	71	-1.0	-320	-2	-568	3	-2.0	-59
LA	98	597	-1.0	-2687	-1	-2388	77	-2.5	-1888
MS	97	1,177	-1.0	-5297	-1	-4708	121	-2.5	-2968
MO	97	425	-1.0	-1913	-1	-1700	88	-2.5	-2158
NM	72	40	-3.0	-540	0	0	0	0	0
NC	99	806	-2.5	-9068	-2	-6448	8	-1.0	-79
OK	95	243	-1.0	-1094	0	0	12	-6.0	-706
SC	94	249	-2.5	-2801	-1	-996	27	-1.0	-265
TN	100	637	-1.0	-2867	-1	-2548	64	-2.5	-1570
TX	61	3,621	-1.0	-16295	0	0	885	-1.5	-13023
VA	100	93	-2.5	-1046	-1	-372	0	0	0
US	**80**	**11,128**	**-1.7**	**-63,157**	**-0.9**	**-34,184**	**2,174**	**-2.3**	**-59,989**

[1, 5, 6]Based on the National Center for Food and Agricultural Policy's 2002 report
[2]Calculated at $4.50/A for each tillage
[3]As suggested by cotton Weed Specialists
[4]Calculated at $4.00/A for each application
[7]Calculated at $9.81/hr (based on farm labor wage rates reported by NASS for 2005) of handweeding times the number of acres on which handweeding is estimated reduced

Table 5.7. Adoption costs[1] of herbicide-resistant (HR) cotton in 2005

State	Total HR cotton Acreage	Glyphosate-resistant cotton acreage	Adoption costs of glyphosate-resistant cotton	Glufosinate-resistant cotton acreage	Adoption costs of glufosinate-resistant cotton	Total adoption costs of HR cotton
	000A	000A	000$	000A	000$	000$
AL	519	519	14532	0	0	14532
AZ	152	152	4256	0.2	3.0	4259
AR	1,042	1,029	28812	13.3	199.5	29012
CA	186	182	5096	4.1	61.5	5158
FL	78	78	2184	0	0	2184
GA	1,192	1,185	33180	6.6	99.0	33279
KS	71	71	1988	0	0	1988
LA	597	596	16688	1	15.0	16703
MS	1,177	1,163	32564	13.8	207.0	32771
MO	425	425	11900	0.2	3.0	11903
NM	40	40	1120	0	0	1120
NC	806	805	22540	1.3	19.5	22560
OK	243	243	6804	0	0	6804
SC	249	249	6972	0.2	3.0	6975
TN	637	632	17696	5.1	76.5	17773
TX	3,621	3,334	93352	286.7	4301.0	97653
VA	93	91	2548	2.1	31.5	2580
US	**11,128**	**10,794**	**302,232**	**335**	**5,020**	**307,254**

[1]Assumptions on adoption costs for 2005 are based on surveys of Extension Specialists and chemical company representatives; technology fee for glyphosate-resistant cotton = $28.00/acre; seed premium/technology fee costs for Liberty Link cotton = $15.00/acre.

Table 5.8. Summary of weed management cost changes in cotton due to biotechnology-derived herbicide-resistant varieties in 2005[1]

State	Herbicide costs	Application costs	Adoption costs	Tillage costs	Hand weeding costs	Total
	000$/year					
AL	-7053	0	14532	-4671	-383	2425
AZ	-3983	-608	4259	-1710	-1805	-3847
AR	-13221	-8336	29012	-4689	-8240	-5474
CA	-4149	-744	5158	-2093	-25349	-27177
FL	218	0	2184	-702	0	1700
GA	-21774	-4768	33279	-5364	-1496	-123
KS	-761	-568	1988	-320	-59	280
LA	-11897	-2388	16703	-2687	-1888	-2159
MS	-20960	-4708	32771	-5297	-2968	-1162
MO	-3920	-1700	11903	-1913	-2158	2212
NM	336	0	1120	-540	0	916
NC	-17666	-6448	22560	-9068	-79	-10701
OK	2544	0	6804	-1094	-706	7548
SC	-4534	-996	6975	-2801	-265	-1621
TN	-19130	-2548	17773	-2867	-1570	-8342
TX	-63645	0	97653	-16295	-13023	4690
VA	989	-372	2580	-1046	0	2151
US	**-188,606**	**-34,184**	**307,254**	**-63,157**	**-59,989**	**-38,682**

[1]Compiled based on data from Tables 5.5, 5.6, and 5.7

Table 5.9. Impact of biotechnology-derived herbicide-resistant varieties on no-till cotton acreage in the United States

Year	No-till acreage (Million acres)	No-till acreage as a % of total	% Increase in no-till acreage based on 1996
1996	0.51	3.4	-
1997	0.53	3.7	4
1998	0.67	4.9	31
2000	1.35	8	166
2002	2.03	14	300
2004	2.40	18	371

Source: Conservation Technology Information Center

References

Agricultural Marketing Service. Cotton Varieties Planted, United States, 2005 Crop.

Banks, J. Oklahoma State University. Personal Communication. 2006.

Barber, T. Mississippi State University. Personal Communication. 2006.

Brecke, B. University of Florida. Personal Communication. 2006.

Culpepper, A.S. 2003. Cotton Production Workshop. University of Georgia. Online Publication. 2003.

Culpepper, S. University of Georgia. Personal Communication. 2006.

Conservation Technology Information Center. Available at http://www.ctic.purdue.edu/ Core4/Core4Main.html.

Delta Farm Press. 2006. Japan and Mexico approve imports of Flex cottonseed. Available at http://www.keepmedia.com/pubs/DeltaFarmPress/2006/03/24/1357377?extID=10032&oliID=213

Doane Marketing Research. 2002. Conservation Tillage Study prepared for the Cotton Foundation. Available at http://www.cotton.org/tech/biotech/presentation /doanecontillfinalreport.ppt

Ferrell, J. A. and G. E. MacDonald. 2005. University of Florida's Agronomy Department's Document Number SS-AGR-16 entitled 'Approximate Herbicide Pricing – 2005'.

Hayes, R. University of Tennessee. Personal Communication. 2006.

Kendig, A. University of Missouri. Personal Communication. 2006.

Lemon, R., T. Baughman, R. Boman, P. Dotray, and P.Baumann. 2004. LibertyLink cotton system. Available at http://lubbock.tamu.edu/cotton/pdf/liblinkcot. pdf#search='bayer%20label%20cotton%20liberty%20link'

McCloskey, W. University of Arizona. Personal Communication. 2006.

McWilliams, D. New Mexico State University. Personal Communication. 2006.

Miller, D. Louisiana State University. Personal Communication. 2006.

Monsanto. 2006. Roundup Ready Flex cotton field trials document greater efficiency for farmers. Available at https://www.monsanto.com/monsanto/layout/media/06/03-06-06.asp.

Murdock, S. W. 2006. Roundup Ready Flex cotton – 2006 launch. Proceedings of the 2006 Beltwide Cotton Conference Conferences. Available at http://www.cotton.org/beltwide/

National Agricultural Statistics Service. 2005 Acreage. Available at http://www.usda.gov/nass.

North, S. Bayer representative in Alabama. Personal communication. 2006.

Norsworthy, J. Clemson University. Personal Communication. 2006.

Patterson, M. University of Auburn. Personal Communication. 2006.

Sankula, S., and E. Blumenthal. Impacts on US Agriculture of Biotechnology-Derived Crops Planted in 2003– An Update of Eleven Case Studies. Available at http://www.ncfap.org/.

Smith, K. University of Arkansas. Personal Communication. 2006.

Vargas, R. University of California at Davis. Personal Communication. 2006.

Wilson, H. Virginia Tech University. Personal Communication. 2006.

York, A. North Carolina State University. Personal Communication. 2006.

6. Soybean

About 88% of the US soybean acreage was planted to biotechnology-derived herbicide-resistant varieties in 2005 (Table 6.1). Overall acreage planted to soybean declined by 1.91 million acres or 2.5% in 2005 compared with 2004, a year when soybean acreage hit the record high mark. Consequently, planted acreage of herbicide-resistant soybean increased by only 0.62 million acres or 1% in 2005 as opposed to 4.62 million acres or 8% in 2004 compared to the respective year before.

Except for Michigan, all the thirty states analyzed in this report planted at least 81% or more of their soybean acres to biotechnology-derived herbicide-resistant varieties in 2005 (Table 6.1). Adoption was lowest, at 75%, for Michigan. While eighteen states had an adoption rate of over 90%, adoption in twelve states exceeded 82%. Adoption of herbicide-resistant soybean was greatest in Florida (100%) followed by West Virginia (99%), Georgia (98%), and South Carolina (98%). Adoption reached 95% in six states that included Alabama, Louisiana, Mississippi, Missouri, Nebraska, and Tennessee. Number of acres planted to biotechnology-derived soybean, however, was highest in Iowa (9.2 million acres) followed by Illinois (7.9 million acres) in 2005.

The simplicity, flexibility, safety, and economics of the weed management programs based on glyphosate have positively influenced the adoption of herbicide-resistant soybean in the United States in 2005, similar to years before. Using glyphosate as the primary herbicide in soybean, growers realized greater flexibility in timing herbicide applications, simplicity with less confusion of herbicide mixes and rates, effective control of perennial and other problem weeds, excellent crop safety, and economic weed control. For these reasons, adoption of glyphosate-resistant soybean has been more rapid than any other new technologies in the history of agriculture.

Herbicides used for weed management in soybean along with their costs are presented in Table 6.2. A survey of soybean specialists offered many different weed management programs that could be used in conventional soybean. The most typical of these programs, which could provide weed control equivalent to that of glyphosate in herbicide-resistant soybean, is presented in Table 6.3. A majority of these programs in conventional soybean featured a preemergence application (using 1 – 2 herbicides) followed by one postemergence application (with 1 – 2 herbicides). On the other hand, herbicide applications in glyphosate-resistant soybean were comprised of one timely application of glyphosate alone at 0.95 lb ai/A in most states (Table 6.4). In only 5 states (Florida, Mississippi, Missouri, Ohio, and Tennessee), 2 applications of glyphosate (at 0.72 lb ai/A each) were routinely used in glyphosate-resistant soybean.

Comparative herbicide use rates and associated costs of weed management in conventional and herbicide-resistant soybean are presented in Table 6.4. Weed management costs associated with glyphosate-resistant soybean are presented in Table 6.5. Weed management costs included royalty fee (the fees that seed companies pay Monsanto to obtain the license to access the technology; typically these costs are passed on to the grower) costs of $10/acre. There has been a 25% increase in royalty fees in 2005 compared with 2004.

Table 6.6 represents changes in herbicide applications along with resulting grower cost savings due to glyphosate-resistant soybean in 2005. Analysis indicated that soybean growers that planted glyphosate-resistant varieties reduced the overall number of herbicide applications by 39.4 million, which translated to cost savings of $134 million.

The aggregate impacts of replacing herbicide programs in conventional soybean with glyphosate-based programs are simulated in Table 6.7. On average, glyphosate-resistant soybean programs used 1.03 lb ai/A at a cost of $21.28 per acre in 2005. Conventional herbicide programs, on the other hand, used an additional 0.32 lb ai/A or 32% more herbicide active ingredients at an additional cost of $18.09. Overall, American soybean growers saved $1.17 billion on weed management costs due to a switch to glyphosate programs in 2005, in spite of added costs due to royalty fees. Additionally, soybean growers have reduced herbicide use by 0.32 lb ai/acre or 20.5 million pounds nationally in 2005.

Overall savings in weed management costs due to glyphosate-resistant soybean were lower in 2005 compared to 2004 ($1.17 billion versus $1.37 billion in 2005 and 2004, respectively). This is mainly due to an increase in royalty fees in 2005. There was a 25% increase in royalty fees or Roundup Ready technology licensing fees in soybean in 2005. Furthermore, changes in weed management programs suggested by the Weed Specialists accounted for some of the reduction in savings. With the phase-out of herbicides such as Canopy XL, new weed management programs were suggested for conventional soybean, which accounted for changes in weed management costs and reduction in cost savings.

A significant impact of the adoption of herbicide-resistant soybean is an increase in no-till acreage. In 1995, one year before the commercialization of glyphosate- resistant soybean, approximately 27% of the total full-season soybean acres in the United States were under no-till production (Table 6.8). With the increasing acreage of glyphosate-resistant soybean, no-till acres also are on the rise. By 2004, the recent year for which estimates are available, about 36% of the total soybean acreage in the United States was planted using no-tillage production practices (Conservation Technology Information Center). This represents a 64% increase in the no-till soybean acreage since the introduction of glyphosate- resistant soybean. No-till farming practices aid in decreased soil erosion, dust, and pesticide run-off and in increased soil moisture retention and improved air and water quality.

Table 6.1. Adoption of glyphosate-resistant (RR) soybean in the United States in 2005

State	Area planted[1]	RR soybean adoption	RR soybean acres	Source[1, 2]
	000A	**%**	**000A**	
AL	150	95	143	Delaney
AR	3000	92	2760	NASS
DE	180	90	162	VanGessel
FL	11	100	11	Brecke
GA	200	98	196	Prostko
IL	9700	81	7857	NASS
IN	5500	89	4895	NASS
IA	10100	91	9191	NASS
KS	2900	90	2610	Peterson/NASS
KY	1260	84	1058	Thurston
LA	900	95	855	Griffin
MD	460	90	414	Kenworthy
MI	1950	75	1463	Sprague
MN	6800	83	5644	NASS
MS	1600	95	1520	Shaw
MO	5100	95	4845	Kendig
NE	5000	95	4750	Martin
NJ	103	90	93	VanGessel
NY	200	90	180	Hahn
NC	1550	88	1364	Dunphy
ND	3250	89	2893	NASS
OH	4450	85	3783	Loux
OK	300	85	255	Medlin
PA	460	84	386	Curran
SC	440	98	431	Main
SD	4050	90	3645	Moechnig
TN	1230	95	1169	Hayes
TX	300	82	246	Miller
VA	540	83	448	Holshouser
WV	19	99	19	Chandran
WI	1600	84	1344	NASS
Total	**73,303**	**88**	**64,630**	

[1]Source: National Agricultural Statistics Service: 2005 Acreage

[2]Affiliations for the Crop Specialists that provided the soybean adoption information are listed in the References section

Table 6.2. Use rates and costs for soybean herbicides in 2005

Trade name	Common Name	Rate (formulated product/A)	Rate (Lb ai/A)	Cost[1] ($/A)
Assure II	Quizalofop	8 oz	0.1	8.15
Boundary	Metribuzin + s-Metolachlor	1.5 pt	1.22	12.20
Canopy	Chlorimuron + Metribuzin	4 oz	0.19	7.79[2]
Classic	Chlorimuron	0.67 oz	0.01	9.05
Dual II Magnum	S-Metolachlor	1.5 pt	1.43	19.68
FirstRate	Cloransulam methyl	0.3 oz	0.016	7.95
Flexstar	Fomesafen	1 pt	0.24	12.50
Frontrow	Cloransulam + Flumetsulam	0.42 oz	0.022	9.33[2]
Fusion	Fluazifop + Fenoxaprop	10 oz	0.21	11.70
Gangster	Flumioxazin + Cloransulam methyl	2.4 oz	0.08	14.55
Harmony Extra	Thifensulfuron	0.5 oz	0.024	6.50
Poast	Sethoxydim	1.0 pt	0.19	8.15
Prowl	Pendimethalin	3.6 pt	1.5	9.20
Prowl H20	Pendimethalin	1.5 pt	0.71	5.63
Pursuit	Imazethapyr	1.44oz	0.063	15.12
Pursuit Plus	Imazethapyr + Pendimethalin	2.5 pt	0.94	15.00
Python	Flumetsulam	1.0 oz	0.053	9.50
Raptor	Imazamox	5 oz	0.039	20.50
Reflex	Fomesafen	1.5 pt	0.375	17.85
Select	Clethodim	8 oz	0.125	12.20
Sencor	Metribuzin	0.5 lb	0.38	8.00
Storm	Acifluorfen + Bentazon	1.5 pt	0.75	14.22[2]
Squadron	Imazaquin + Pendimethalin	3 pt	0.88	13.84[2]
Treflan	Trifluralin	2.0 pt	1.0	6.50
Ultra blazer	Acifluorfen	1.5 pt	0.375	13.50
Roundup WeatherMAX	Glyphosate	22 oz	0.95	9.63

[1]Herbicide costs were calculated based on the '2005 North Dakota Herbicide Compendium' compiled by the North Dakota State University.
[2]Prices for Canopy, Frontrow, Storm, and Squadron are estimated based on 2004 and 2006 prices.

Table 6.3. Herbicide program that would provide weed control equivalent to glyphosate[1]

State	Conventional program	Source[2]
AL	Squadron fb[3] Storm + Select	Delaney
AR	Squadron fb Storm + Select	Talbert
DE	Canopy + Dual II Magnum fb Reflex + Poast (Dual II Magnum at 1.25 pt, Reflex at 1 pt, and all other herbicides at standard rates shown in Table 6.2)	VanGessel
FL	Prowl + Sencor fb Classic	Brecke
GA	Treflan + Sencor fb Classic	Prostko
IL	Boundary fb Flexstar + Fusion	Hager
IN	Dual II Magnum + Pursuit fb Storm	Bauman
IA	Canopy fb Reflex + Select	Hartzler
KS	Boundary fb FirstRate + Select	Peterson
KY	Flexstar + Select	Green
LA	Squadron fb Storm + Select	Griffin
MD	Dual II Magnum + Python	Ritter
MI	Boundary fb Flexstar + Fusion	Sprague
MN	Boundary fb Fusion + Reflex	Gunsolus
MS	Dual II Magnum fb Frontrow + Select	Poston
MO	Boundary fb Flexstar + Fusion	Bradley
NE	Pursuit Plus + Ultra Blazer	Martin
NJ	Canopy + Dual II Magnum fb Reflex + Poast (Dual II Magnum at 1.25 pt, Reflex at 1 pt, and all other herbicides at standard rates shown in Table 6.2)	VanGessel
NY	Dual II Magnum + Python + Sencor	Hahn
NC	Squadron fb Storm + Select	York
ND	Flexstar + Raptor	Zollinger
OH	Gangster fb Flexstar + Select	Loux
OK	Dual II Magnum fb Reflex	Medlin
PA	Dual II Magnum + Python fb Reflex (at half-rate)	Curran
SC	Prowl H20 + Classic fb FirstRate + Assure II	Main
SD	Boundary fb FirstRate + Select	Wrage
TN	Squadron fb Flexstar + Select	Hayes
TX	Prowl fb Ultra Blazer + Select	Miller
VA	Pursuit + prowl fb Pursuit + Dual II Magnum (POST program at half-rate)	Holshouser
WV	Prowl fb Pursuit + Dual II Magnum (at half-rate)	Chandran
WI	Raptor + Ultra Blazer	Boerboom

[1]Survey respondents specified several alternative programs that would be equally effective. For the purpose of this analysis, a single program is selected as above
[2]Affiliations for Weed Specialists that provided the above information are listed in the References section
[3]fb = followed by

Table 6.4. Comparative herbicide costs and use rates in glyphosate-resistant (Roundup Ready) and conventional soybean in 2005[1]

State	Glyphosate-resistant soybean		Conventional soybean	
	$/A	lb ai/A	$/A	lb ai/A
AL	19.63	0.95	40.26	1.76
AR	19.63	0.95	40.26	1.76
DE	19.63	0.95	44.24	1.82
FL	24.60	1.44	26.25	1.89
GA	19.63	0.95	23.55	1.39
IL	19.63	0.95	36.40	1.67
IN	19.63	0.95	49.02	2.24
IA	25.10	0.91[2]	37.84	0.69
KS	19.63	0.95	32.35	1.36
KY	19.63	0.95	24.70	0.37
LA	19.63	0.95	40.26	1.76
MD	19.63	0.95	38.11	1.48
MI	19.63	0.95	36.40	1.67
MN	19.63	0.95	41.75	1.81
MS	24.60	1.44	41.21	1.58
MO	24.60	1.44	36.40	1.67
NE	19.63	0.95	28.50	1.32
NJ	19.63	0.95	44.24	1.82
NY	19.63	0.95	37.18	1.86
NC	19.63	0.95	40.26	1.76
ND	19.63	0.95	33.00	0.28
OH	24.60	1.44	39.25	0.45
OK	19.63	0.95	37.53	1.81
PA	19.63	0.95	38.11	1.67
SC	19.63	0.95	30.78	0.84
SD	19.63	0.95	32.35	1.36
TN	24.60	1.44	38.54	1.25
TX	19.63	0.95	34.90	2.00
VA	19.63	0.95	41.72	2.32
WV	19.63	0.95	34.16	2.28
WI	19.63	0.95	34.00	0.41

[1]Roundup Ready program costs = royalty fee costs + herbicide program costs; Roundup Ready soybean royalty fee costs = $10/A; Cost of Roundup WeatherMax = $9.63/0.95lb ai; herbicide applications in glyphosate-tolerant soybean comprised of one timely application of glyphosate at 0.95 lb ai/A or 2 applications of 0.72 or 0.95 lb ai/A each or PRE application of Canopy at 0.19 lb ai/A followed by glyphosate at 0.72 lb ai/A[2]. Alternative program costs and rates are calculated based on Tables 6.2 and 6.3

Table 6.5. Production costs associated with glyphosate-resistant (RR) soybean in 2005

State	RR soybean acreage	Herbicide use		Royalty fee costs[1]	Herbicide cost[2]	Total cost	Cost/A
	000A	lb ai/A	000 lb/yr.	000$	000$	000$	$/A
AL	143	0.95	136	1430	1377	2807	19.63
AR	2760	0.95	2622	27600	26579	54179	19.63
DE	162	0.95	154	1620	1560	3180	19.63
FL	11	1.44	16	110	161	271	24.60
GA	196	0.95	186	1960	1887	3847	19.63
IL	7857	0.95	7464	78570	75663	154233	19.63
IN	4895	0.95	4650	48950	47139	96089	19.63
IA	9191	0.91[2]	8364	91910	138784	230694	25.10
KS	2610	0.95	2480	26100	25134	51234	19.63
KY	1058	0.95	1005	10580	10189	20769	19.63
LA	855	0.95	812	8550	8234	16784	19.63
MD	414	0.95	393	4140	3987	8127	19.63
MI	1463	0.95	1390	14630	14089	28719	19.63
MN	5644	0.95	5362	56440	54352	110792	19.63
MS	1520	1.44	2189	15200	22192	37392	24.60
MO	4845	1.44	6977	48450	70737	119187	24.60
NE	4750	0.95	4513	47500	45743	93243	19.63
NJ	93	0.95	88	930	896	1826	19.63
NY	180	0.95	171	1800	1733	3533	19.63
NC	1364	0.95	1296	13640	13135	26775	19.63
ND	2893	0.95	2748	28930	27860	56790	19.63
OH	3783	1.44	5448	37830	55232	93062	24.60
OK	255	0.95	242	2550	2456	5006	19.63
PA	386	0.95	367	3860	3717	7577	19.63
SC	431	0.95	410	4310	4151	8461	19.63
SD	3645	0.95	3463	36450	35101	71551	19.63
TN	1169	1.44	1683	11690	17067	28757	24.60
TX	246	0.95	234	2460	2369	4829	19.63
VA	448	0.95	426	4480	4314	8794	19.63
WV	19	0.95	18	190	183	373	19.63
WI	1344	0.95	1277	13440	12943	26383	19.63
Total	**64,630**	**1.03**	**66,583**	**646,300**	**728,964**	**1,375,264**	**21.28**

[1]Calculated at $10/A

[2]Calculated based on Table 6.4.

Table 6.6. Reduction in herbicide applications and application costs due to glyphosate-resistant (RR) soybean in 2005

State	RR soybean acreage	Herbicide applications in conventional soybean[1]	Herbicide applications in RR soybean[2]	Reduction in herbicide applications in RR soybean	Application cost savings due to RR soybean
	000A	#/acre	#/acre	#/acre	000$[3]
AL	143	2	1	1	572
AR	2760	2	1	1	11040
DE	162	2	1	1	648
FL	11	2	2	0	0
GA	196	2	1	1	784
IL	7857	2	1	1	31428
IN	4895	2	1	1	19580
IA	9191	2	2	0	0
KS	2610	2	1	1	10440
KY	1058	1	1	0	0
LA	855	2	1	1	3420
MD	414	1	1	0	0
MI	1463	2	1	1	5852
MN	5644	2	1	1	22576
MS	1520	2	2	0	0
MO	4845	2	2	0	0
NE	4750	1	1	0	0
NJ	93	2	1	1	372
NY	180	1	1	0	0
NC	1364	2	1	1	5456
ND	2893	1	1	0	0
OH	3783	2	2	0	0
OK	255	2	1	1	1020
PA	386	2	1	1	1544
SC	431	2	1	1	1724
SD	3645	2	1	1	14580
TN	1169	2	2	0	0
TX	246	2	1	1	984
VA	448	2	1	1	1792
WV	19	2	1	1	76
WI	1344	1	1	0	0
Total	**64,630**	**1.81**	**1.19**	**0.61**	**133,888**

[1]Based on data from Table 6.3
[2]Based on data from Table 6.4
[3]Herbicide application costs in 2005 = $4.00/acre

Table 6.7. Aggregate impacts of glyphosate-resistant (RR) soybean in 2005

	RR soybean acreage	Changes in			
State		Production costs		Herbicide use	
	000A	$/A	000$[1]	lb ai/A	000 lb
AL	143	-24.63	-3521	-0.81	-116
AR	2760	-24.63	-67978	-0.81	-2236
DE	162	-28.61	-4635	-0.87	-141
FL	11	-1.65	-18	-0.45	-5
GA	196	-7.92	-1552	-0.44	-86
IL	7857	-20.77	-163190	-0.72	-5657
IN	4895	-33.39	-163444	-1.29	-6315
IA	9191	-12.74	-117093	0.22	2022
KS	2610	-16.72	-43639	-0.41	-1070
KY	1058	-5.07	-5364	0.58	614
LA	855	-24.63	-21059	-0.81	-693
MD	414	-18.48	-7651	-0.53	-219
MI	1463	-20.77	-30387	-0.72	-1053
MN	5644	-26.12	-147421	-0.86	-4854
MS	1520	-16.61	-25247	-0.14	-213
MO	4845	-11.8	-57171	-0.23	-1114
NE	4750	-8.87	-42133	-0.37	-1758
NJ	93	-28.61	-2661	-0.87	-81
NY	180	-17.55	-3159	-0.91	-164
NC	1364	-24.63	-33595	-0.81	-1105
ND	2893	-13.37	-38679	0.67	1938
OH	3783	-14.65	-55421	0.99	3745
OK	255	-21.9	-5585	-0.86	-219
PA	386	-22.48	-8677	-0.72	-278
SC	431	-15.15	-6530	0.11	47
SD	3645	-16.72	-60944	-0.41	-1494
TN	1169	-13.94	-16296	0.19	222
TX	246	-19.27	-4740	-1.05	-258
VA	448	-26.09	-11688	-1.37	-614
WV	19	-18.53	-352	-1.33	-25
WI	1344	-14.37	-19313	0.54	726
Total	**64,630**	**-18.09**	**-1,169,143**	**-0.32**	**-20,454**

[1]Includes cost savings due to herbicide use (Table 6.5) and herbicide application (Table 6.6)

Table 6.8. Trends in no-till full-season soybean acreage in the United States[a]

U.S. soybean acreage	1995	1996	1997	1998	2000	2002	2004
.	------------------------------- Million acres -------------------------------------						
Total	58.8	60.6	65.1	66.6	70.0	69.8	71.42
No-till	15.9	16.2	17.9	19.0	21.5	23.1	26.02
No till as a % of total	27	27	28	29	31	33	36
% Increase in no-till acreage	-	2	13	20	35	45	64

[a]Data is not available for 1999

Source: Conservation Technology Information Center

References

Bauman, T. Purdue University. Personal communication. 2006.

Boerboom, C. University of Wisconsin. Personal communication. 2006.

Bradley, K. University of Missouri. Personal communication. 2006.

Brecke, B. University of Florida, Personal communication. 2006.

Chandran, R. University of West Virginia. Personal communication. 2006.

Conservation Technology Information Center. Available at http://www.ctic.purdue.edu/Core4/Core4Main.html.

Curran, W. Pennsylvania State University. Personal communication. 2006.

Delaney, D. Auburn University. Personal communication. 2006.

Dunphy, J. North Carolina State University. Personal communication. 2006.

Green, J. University of Kentucky. Personal communication. 2006.

Griffin, J. Louisiana State University. Personal communication. 2006.

Gunsolous, J. University of Minnesota. Personal communication. 2006.

Hager, A. University of Illinois. Personal communication. 2006.

Hahn, R. Cornell University. Personal communication. 2006.

Hartzler, R. Iowa State University. Personal communication. 2006.

Hayes, R. University of Tennessee. Personal communication. 2006.

Holshouser, D. Virginia Polytechnic University. Personal communication. 2006

Kendig, A. University of Missouri. Personal communication. 2006.

Kenworthy, W. University of Maryland. Personal communication. 2006

Loux, M. Ohio State University. Personal communication. 2006.

Main, C. Clemson University. Personal communication. 2006

Martin, A. University of Nebraska. Personal communication. 2006.

Medlin, C. Oklahoma State University. Personal communication. 2006.

Miller, T. Texas A&M University. Personal communication. 2006

Moechnig, M. South Dakota State University. Personal communication. 2006.

National Agricultural Statistics Service. 2005 Acreage. Available at http://www.usda.gov/nass.

North Dakota State University. 2005 North Dakota Weed Control Guide.

Peterson, D. Kansas State University. Personal communication. 2006.

Poston, D. Mississippi State University. Personal communication. 2006.

Prostko, E. University of Georgia. Personal communication. 2006.

Ritter, R. University of Maryland. Personal communication. 2006.

Shaw, A. Mississippi State University. Personal communication. 2006.

Sprague, C. Michigan State University. Personal communication. 2006.

Talbert, R. University of Arkansas. Personal communication. 2005.

Thurston, R. Kentucky Agricultural Statistics Service. Personal communication. 2006.

VanGessel, M. University of Delaware. Personal communication. 2006.

York, A. North Carolina State University. Personal communication. 2006.

Zollinger, R. North Dakota State University. Personal communication. 2005.

Insect-resistant crops

Three applications of Bt corn (YieldGard Corn Borer, Herculex I, and YieldGard RW) and 2 applications of Bt cotton (Bollgard and Bollgard II) were in commercial production in 2005, as in 2004. Impacts were calculated for all the Bt applications except for Herculex I corn in this report.

Since the first planting of insect-resistant/Bt crops, growers noted that the most substantial impact has been improvement in crop yields. Unlike conventional insecticides, Bt crops offered in-built, season-long, and enhanced pest protection, which translated to gained yields. Another significant impact of insect-resistant crops has been the reduction in insecticide use targeted against key pests because Bt crops eliminate the need for insecticide applications. Reduction in overall insecticide use and number of insecticide sprays has led to a reduction in overall input costs for the adopters of Bt crops. Other benefits from Bt crops include reduced scouting needs, pesticide exposure to applicators, and energy use. The agronomic and economic impacts from Bt corn and cotton for 2005 crop season are analyzed and discussed in the following case studies.

7. Corn borer-resistant corn (YieldGard Corn Borer/IR-I)

Two varieties of biotechnology-derived corn provided protection against European corn borer (ECB) and southwestern corn borer (SWCB) in 2005, similar to 2004 and 2003. These include YieldGard Corn Borer and Herculex I. YieldGard Corn Borer corn was planted on roughly 34% of the total planted corn acreage in 2005 (Table 7.1). It is estimated that Herculex I corn was planted on roughly 3 to 4% of the total acreage in 2005.

In view of the non-availability of the state-by-state adoption estimates for the Herculex I trait, impacts were not presented for Herculex I corn in this report. Therefore, impacts presented in this case study pertain to YieldGard Corn Borer only.

About 34 US states planted 27.9 million acres of corn to biotechnology-derived corn borer-resistant (YieldGard Corn Borer) varieties in 2005 (Table 7.1). On a percent basis, adoption was highest in Arizona (77%) followed by New Mexico (62%) and South Dakota (52%). Iowa, with 5.4 million acres, has the largest planted acreage of YieldGard Corn Borer in 2005 (Table 7.1).

YieldGard Corn Borer varieties were planted on 34% more corn acreage in 2005 compared to 2004 (27.9 million acres in 2005 versus 20.9 million acres in 2004). The significant rise in the adoption of YieldGard Corn Borer varieties in 2005 is due to the availability of stacked products for corn pest management. YieldGard Plus trait, which is the stacked product of YieldGard Corn Borer and YieldGard RW was available for commercial planting in 2005. In addition to the YieldGard Plus, a triple trait/stacked product, YieldGard Plus with Roundup Ready 2 Corn technology, was also available in limited quantities in 2005.

Case study 7 represents the impacts due to ECB and SWCB control resulting from the use of YieldGard Corn Borer varieties. YieldGard Corn Borer impact estimates for 2005 were calculated using the same methodology used in our earlier reports. Yield impacts due to corn borers were calculated based on the premise that high infestations usually lead to significant yield losses while low infestations do not. Information on corn borer impacts on yield during a ‘low’ and a ‘high’ infestation year were obtained from the 2001 report. This information was the result of a survey of entomologists who specified the number of years during which infestation was high in a 10-year period.

The survey information on corn borer infestation levels for 36 states is shown in Table 7.2 (Gianessi et al. 2002). Yield losses in ‘high’ infestation years are typically much higher in the Plains states and in states where SWCB is the primary pest (CO, KS, OK, KY, TX). It appears that Alabama is the only state where no yield loss typically occurs due to corn borers (all years are classified as ‘low’ during which the average yield loss is zero).

Table 7.3 displays state-by-state estimates of the aggregate impacts on corn production volume, value, and costs based on current adoption of Bt corn during a ‘low’ and ‘high’ borer infestation year. These estimates compare impacts of Bt corn adoption to an untreated situation where insecticides are not used for borer control. Growers who planted Bt corn are assumed to gain 100% of the lost yield in this situation. Based on the comparisons to an untreated scenario, total production increase on current Bt corn acreage is estimated to range between 130 and 416 million bushels during a low and high year, respectively. In 2005, YieldGard Corn Borer technology cost was $7/A and a bushel of corn was valued at $1.95. Thus, the total value of the increased production is estimated to be $254 and $810 million in a low and high year, respectively. Subtracting the technology fee costs, the net benefit of planting Bt corn was estimated to be $58 and $615 million or $2.09 and $22.04 per acre in low and high years, respectively.

Simulations involving the use of insecticides on current Bt corn acreage are presented in Table 7.4. This table shows state-by-state estimates of potential per acre yield and value that resulted from using insecticides in a 'high' infestation year. Insecticides provide 80% control of corn borers at an average cost of $14/A. Insecticide use is simulated for only high infestation years because in no state does insecticide use return more than the $14/A cost in a low year. Except for Alabama, Indiana, and Mississippi, an insecticide application in a high year has increased net economic returns in all the states in 2005. Insecticide use analysis in a high year indicated that 10.6 million pounds of insecticide will be used and net income would increase by $258 million.

The impacts of the adoption of Bt corn during a typical year out of a normal 10-year cycle are displayed in Table 7.5. The increase in production volume, value, and costs for a low infestation year are based on the use of Bt corn (Table 7.3). For high infestation years, the impact of Bt corn is calculated as the difference between volume, value and cost resulting from the planting of Bt corn (Table 7.3) minus the amounts that would result from use of insecticides (Table 7.4). Thus in a high year, growers gain an extra 20% yield from Bt corn which they would not gain from using insecticides. Bt corn is credited with lowering production costs during a high infestation year because Bt corn costs less than insecticides.

The production volume, value and the production cost estimates for low and high years are weighted by the number of low and high years expected in a normal 10-year cycle to compute estimates for a typical year. Insecticide use is assumed to occur only in high years. The use of insecticides in a typical year is calculated as the product of the number of high years times the estimated insecticide use in a high year divided by ten. The net value of Bt corn adoption during a typical year is calculated as the difference between the increase in production value and the increase in production costs.

Based on the planted acreage of 27.9 million acres in 2005, it was calculated that Bt corn resulted in an increased production of 109.3 million bushels or 6.12 billion pounds of corn valued at $213 million. Net returns due to Bt corn were estimated to be

$197 million. Without the use of Bt corn, approximately 4.85 million additional pounds of insecticides would be used in a typical year. The above estimates imply that corn growers produced 24% more yields, lowered insecticide use by 27%, and increased monetary gains by 26% in 2005, compared to 2004, due to the expanded Bt acreage in 2005.

The selling price of corn was 20% lower in 2005 ($1.95) compared to 2004 ($2.45). In spite of lower corn prices in 2005, growers who planted YieldGard Corn Borer varieties were able to improve the return on their investment by eliminating the yield losses due to corn borer infestations and also by improving per acre corn yields.

Table 7.1. Adoption of YieldGard Corn Borer corn in the United States in 2005

State	Planted corn acreage[1]	Acres planted to YieldGard Corn Borer corn[2]	Adoption of YieldGard Corn Borer corn
	000A	Acres	%
AL	200	44,882	22
AR	240	49,801	21
AZ	50	38,500	77[3]
CA	570	970	0.2
CO	1100	295,725	27
DE	160	68,902	43
GA	270	45,107	17
ID	235	420	0.2
IL	12100	3,494,730	29
IN	5900	1,026,444	17
IA	12800	5,362,242	42
KS	3650	1,639,292	45
KY	1250	261,044	21
LA	340	96,769	28
MD	470	232,406	49
MI	2250	673,547	30
MN	7300	3,608,218	49
MS	380	66,133	17
MO	3100	1,174,665	38
NE	8500	3,758,157	44
NM	140	87,187	62
NY	990	152,095	15
NC	750	231,368	31
ND	1410	502,477	36
OH	3450	399,916	12
OK	290	106,888	37
PA	1350	361,561	27
SD	4450	2,291,998	52
TN	650	239,265	37
TX	2050	460,181	22
VA	490	185,353	38
WA	150	32,130	21
WI	3800	923,017	24
WY	80	182	0.2
Total	**81,165**	**27,911,572**	**34**
US Total/Average	**81,759**	**27,911,572**	**34**

[1]Source: National Agricultural Statistics Service. 2005 Acreage
[2]Source: Doane Marketing Research, Inc.
[3]Source: Clark (2006)

Table 7.2. Corn borer incidence and yield impacts[1, 2]

State	Yield loss (Bu/A)		Number of years out of 10	
	Low	High	Low	High
AL	0.0	8.0	10	0
AR	5.0	30.0	5	5
AZ	7.0	23.0	5	5
CO	7.0	23.0	5	5
CT	3.0	11.0	5	5
DE	3.9	11.2	5	5
GA	5.0	11.0	9	1
ID[3]	7.0	23.0	5	5
IL	4.0	10.0	5	5
IN	3.0	7.0	6	4
IA	5.0	11.0	5	5
KS	5.0	40.0	5	5
KY	2.2	18.9	5	5
LA	4.0	30.0	7	3
MA	3.0	11.0	5	5
MD	8.0	26.0	6	4
MI	4.0	12.0	3	7
MN	4.5	13.0	6	4
MS	2.5	5.5	5	5
MO	5.0	30.0	5	5
MT[3]	5.0	11.0	7	3
NE	5.0	11.0	7	3
NJ	5.0	9.0	3	7
NM	7.0	23.0	5	5
NY	3.0	11.0	5	5
NC	5.0	11.0	2	8
ND	5.0	11.0	7	3
OH	2.0	12.0	8	2
OK	8.0	18.0	5	5
PA	3.3	11.5	7	3
SC	3.0	10.0	8	2
SD	5.0	15.0	5	5
TN	5.0	11.0	7	3
TX	8.0	40.0	2	8
VA	3.0	15.0	9	1
VT	3.0	11.0	5	5
WA[3]	5.0	11.0	7	3
WV	3.0	15.0	9	1
WI	4.0	12. 0	3	7

[1]Includes European and Southwestern corn borer
[2]Information is based on the National Center for Food and Agricultural Policy's 2002 report (Gianessi et al. 2002)
[3]Based on the assumptions from neighboring corn-producing states

Table 7.3. Aggregate impacts of YieldGard Corn Borer adoption[1]

State[2]	Bt acreage	Production volume increase				Production value increase[3]				Bt cost[4]	Total net value	
		Low	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*		*Low*	*High*
	Acres	Bu/A		000 Bu/Year		$/A		000$/Year		000 $/Year	000 $/Year	
AL	44882	0.0	8.0	0	359	0.00	15.60	0	700	314	-314	386
AR	49801	5.0	30.0	249	1494	9.75	58.50	486	2913	349	137	2564
AZ	38500	7.0	23.0	270	886	13.65	44.85	526	1727	270	256	1457
CO	295725	7.0	23.0	2070	6802	13.65	44.85	4037	13263	2070	1967	11193
DE	68902	3.9	11.2	269	772	7.61	21.84	524	1505	482	42	1023
GA	45107	5.0	11.0	226	496	9.75	21.45	440	968	316	124	652
ID	420	7.0	23.0	3	10	13.65	44.85	6	19	3	3	16
IL	3494730	4.0	10.0	13979	34947	7.80	19.50	27259	68147	24463	2796	43684
IN	1026444	3.0	7.0	3079	7185	5.85	13.65	6005	14011	7185	-1180	6826
IA	5362242	5.0	11.0	26811	58985	9.75	21.45	52282	115020	37536	14746	77484
KS	1639292	5.0	40.0	8196	65572	9.75	78.00	15983	127865	11475	4508	116390
KY	261044	2.2	18.9	574	4934	4.29	36.86	1120	9621	1827	-707	7794
LA	96769	4.0	30.0	387	2903	7.80	58.50	755	5661	677	77	4984
MD	232406	8.0	26.0	1859	6043	15.60	50.70	3626	11783	1627	1999	10156
MI	673547	4.0	12.0	2694	8083	7.80	23.40	5254	15761	4715	539	11046
MN	3608218	4.5	13.0	16237	46907	8.78	25.35	31662	91468	25258	6405	66210
MS	66133	2.5	5.5	165	364	4.88	10.73	322	709	463	-141	246
MO	1174665	5.0	30.0	5873	35240	9.75	58.50	11453	68718	8223	3230	60495
NE	3758157	5.0	11.0	18791	41340	9.75	21.45	36642	80612	26307	10335	54305
NM	87187	7.0	23.0	610	2005	13.65	44.85	1190	3910	610	580	3300
NY	152095	3.0	11.0	456	1673	5.85	21.45	890	3262	1065	-175	2197
NC	231368	5.0	11.0	1157	2545	9.75	21.45	2256	4963	1620	636	3343
ND	502477	5.0	11.0	2512	5527	9.75	21.45	4899	10778	3517	1382	7261
OH	399916	2.0	12.0	800	4799	3.90	23.40	1560	9358	2799	-1240	6559
OK	106888	8.0	18.0	855	1924	15.60	35.10	1667	3752	748	919	3004
PA	361561	3.3	11.5	1193	4158	6.44	22.43	2327	8108	2531	-204	5577
SD	2291998	5.0	15.0	11460	34380	9.75	29.25	22347	67041	16044	6303	50997
TN	239265	5.0	11.0	1196	2632	9.75	21.45	2333	5132	1675	658	3457
TX	460181	8.0	40.0	3681	18407	15.60	78.00	7179	35894	3221	3958	32673
VA	185353	3.0	15.0	556	2780	5.85	29.25	1084	5422	1297	-213	4125
WA	32130	5.0	11.0	161	353	9.75	21.45	313	689	225	88	464
WI	923017	4.0	12.0	3692	11076	7.80	23.40	7200	21599	6461	738	15138
Total	**27,910,420**			**129,791**	**415,579**			**253,627**	**810,379**	**195,373**	**58,254**	**615,006**

[1]Compared to an untreated scenario
[2]California and Wyoming are not included in the analysis
[3]Calculated at $1.95/Bushel (Source: National Agricultural Statistics Service)
[4]Calculated at $7.00/Acre

Table 7.4. Aggregate impacts of simulated insecticide use for corn borer control in a high infestation year

State	Bt acreage	Production increase				Insecticide cost	Total net value		Insecticide use
		Volume		Value					
	Acres	Bu/A[1]	000 Bu/Yr	$/A[2]	000 $/Yr	000 $/Yr[3]	$/A	000 $/Yr	Lb/Yr[4]
AL	44882	6.4	287	12.48	560	628	-1.52	-68	17055
AR	49801	24	1195	46.80	2331	697	32.80	1633	18924
AZ	38500	18.4	708	35.88	1381	539	22	842	14630
CO	295725	18.4	5441	35.88	10611	4140	21.88	6470	112376
DE	68902	8.96	617	17.47	1204	965	3.47	239	26183
GA	45107	8.8	397	17.16	774	631	3.16	143	17141
ID	420	18.4	8	35.88	15	6	21.88	9	160
IL	3494730	8	27958	15.60	54518	48926	1.60	5592	1327997
IN	1026444	5.6	5748	10.92	11209	14370	-3.08	-3161	390049
IA	5362242	8.8	47188	17.16	92016	75071	3.16	16945	2037652
KS	1639292	32	52457	62.40	102292	22950	48.40	79342	622931
KY	261044	15.12	3947	29.48	7697	3655	15.48	4042	99197
LA	96769	24	2322	46.80	4529	1355	32.80	3174	36772
MD	232406	20.8	4834	40.56	9426	3254	26.56	6173	88314
MI	673547	9.6	6466	18.72	12609	9430	4.72	3179	255948
MN	3608218	10.4	37525	20.28	73175	50515	6.28	22660	1371123
MS	66133	4.4	291	8.58	567	926	-5.42	-358	25131
MO	1174665	24	28192	46.80	54974	16445	32.80	38529	446373
NE	3758157	8.8	33072	17.16	64490	52614	3.16	11876	1428100
NM	87187	18.4	1604	35.88	3128	1221	21.88	1908	33131
NY	152095	8.8	1338	17.16	2610	2129	3.16	481	57796
NC	231368	8.8	2036	17.16	3970	3239	3.16	731	87920
ND	502477	8.8	4422	17.16	8623	7035	3.16	1588	190941
OH	399916	9.6	3839	18.72	7486	5599	4.72	1888	151968
OK	106888	14.4	1539	28.08	3001	1496	14.08	1505	40617
PA	361561	9.2	3326	17.94	6486	5062	3.94	1425	137393
SD	2291998	12	27504	23.40	53633	32088	9.40	21545	870959
TN	239265	8.8	2106	17.16	4106	3350	3.16	756	90921
TX	460181	32	14726	62.40	28715	6443	48.40	22273	174869
VA	185353	12	2224	23.40	4337	2595	9.40	1742	70434
WA	32130	8.8	283	17.16	551	450	3.16	102	12209
WI	923017	9.6	8861	18.72	17279	12922	4.72	4357	350746
Total	**27,910,420**		**332,461**		**648,303**	**390,746**		**257,557**	**10,605,960**

[1]Calculated at 80% of the increase attributed to Bt corn

[2]Calculated at $1.95/Bushel

[3]Calculated at $14/Acre

[4]Calculated at 0.38 lb ai/Acre

Table 7.5. Aggregate impacts of Bt corn adoption: typical year

State	# Years out of 10		Production volume increase			Production value increase			Production cost			Net value	Insecticide use[4]
	Low	High	Low[1]	High[2]	Typical[3]	Low	High	Typical	Low	High	Typical	Typical	Typical
			000 Bu/Year			000 $/Year			000 $/Year			000 $/Year	Lb ai/Year
AL	10	0	0	72	0	0	140	0	314	-314	314	-314	0
AR	5	5	249	299	274	486	582	534	349	-348	1	534	9462
AZ	5	5	270	178	224	526	346	436	270	-269	1	570	7315
CO	5	5	2070	1361	1716	4037	2652	3345	2070	-2070	0	3345	56188
DE	5	5	269	155	212	524	301	413	482	-483	-1	414	13092
GA	9	1	226	99	213	440	194	415	316	-315	253	160	1714
ID	5	5	3	2	3	6	4	5	3	-3	0	5	80
IL	5	5	13979	6989	10484	27259	13629	20444	24463	-24463	0	20444	663999
IN	6	4	3079	1437	2422	6005	2802	4724	7185	-7185	1437	3287	156020
IA	5	5	26811	11797	19304	52282	23004	37643	37536	-37535	1	37642	1018826
KS	5	5	8196	13115	10656	15983	25573	20778	11475	-11475	0	20778	311466
KY	5	5	574	987	781	1120	1924	1522	1827	-1828	-1	1523	49599
LA	7	3	387	581	445	755	1132	868	677	-678	271	597	11032
MD	6	4	1859	1209	1599	3626	2357	3118	1627	-1627	325	2793	35326
MI	3	7	2694	1617	1940	5254	3152	3783	4715	-4715	-1886	5669	179164
MN	6	4	16237	9382	13495	31662	18293	26314	25258	-25257	5053	21261	548449
MS	5	5	165	73	119	322	142	232	463	-463	0	232	12566
MO	5	5	5873	7048	6461	11453	13744	12599	8223	-8222	1	12598	223187
NE	7	3	18791	8268	15634	36642	16122	30486	26307	-26307	10523	19963	428430
NM	5	5	610	401	506	1190	782	986	610	-611	-1	987	16566
NY	5	5	456	335	396	890	652	771	1065	-1064	1	770	28898
NC	2	8	1157	509	639	2256	993	1246	1620	-1619	-971	2217	70336
ND	7	3	2512	1105	2090	4899	2155	4076	3517	-3518	1407	2669	57282
OH	8	2	800	960	832	1560	1872	1622	2799	-2800	1679	-57	30394
OK	5	5	855	385	620	1667	751	1209	748	-748	0	1209	20309
PA	7	3	1193	832	1085	2327	1622	2116	2531	-2531	1012	1104	41218
SD	5	5	11460	6876	9168	22347	13408	17878	16044	-16044	0	17878	435480
TN	7	3	1196	526	995	2333	1026	1941	1675	-1675	670	1271	27276
TX	2	8	3681	3681	3681	7179	7179	7179	3221	-3222	-1933	9112	139895
VA	9	1	556	556	556	1084	1085	1084	1297	-1298	1038	46	7043
WA	7	3	161	70	134	313	138	261	225	-225	90	171	3663
WI	3	7	3692	2215	2658	7200	4320	5184	6461	-6461	-2584	7768	245522
Total			**129,791**	**83,120**	**109,338**	**253,627**	**162,076**	**213,210**	**195,373**	**-195,373**	**16,700**	**196,646**	**4,849,792**

[1]Low: Aggregate increase from Bt corn compared to untreated.

[2]High: Difference between aggregate increase from Bt corn and aggregate increase from insecticide use.

[3]Typical: Low and High aggregate values weighted by the number of low and high years.

[4]Insecticide use: Use in high year weighted by the number of high years divided by 10.

References

Clark, L. University of Arizona. Personal communication. 2006.

Doane's Marketing Research, Inc. (DMR). 2006. 2005 Corn Trait Data.

Gianessi, L. P., C. S. Silvers, S. Sankula, and J. E. Carpenter. 2002. Plant biotechnology: current and potential impact for improving pest management in US agriculture, an analysis of 40 case studies. Available at http://www.ncfap.org/whatwedo/biotech-us.php.

National Agricultural Statistics Service. 2005 Acreage. Available at http://www.usda.gov/nass.

National Agricultural Statistics Service. 2005 Agricultural Prices. Available at http://www.usda.gov/nass

8. Rootworm-resistant corn (YieldGard RW/IR-II)

The year 2005 was the third year of the commercial planting of YieldGard RW corn. American corn growers planted YieldGard RW hybrids on 3.51 million acres of corn acreage in 2005 (Table 8.1). This represented roughly 4% of the total corn acreage planted in the United States. Adoption was highest in Delaware (9%) followed by South Dakota (7%). However, planted YieldGard RW acreage was highest in Iowa followed by Illinois, Minnesota and Indiana.

Planted acreage of YieldGard RW corn increased 166% in 2005 (3.51 million acres) compared with 2004 (1.32 million acres) for three reasons. First, YieldGard RW technology is currently available in hybrids suitable to various regions of the Corn Belt. Second, YieldGard Plus trait, which is the stacked product of YieldGard RW and YieldGard Corn Borer was available for planting in 2005. In addition to the YieldGard Plus, a triple trait/stacked product, YieldGard Plus with Roundup Ready 2 Corn technology, was also available in limited quantities in 2005. Third, the European Union's approval of YieldGard RW corn (MON 863) on August 8, 2005 for import and use in animal feed (Haines 2005) has further increased the adoption in the United States.

YieldGard RW provided a revolutionary alternative in managing one of the most difficult and expensive pest problems in US corn. University trials and grower experiences indicated that YieldGard RW corn sustained lowest or no root injury compared to corn treated with conventional insecticides (Cullen et al., 2004; Estes et al. 2004; Estes et al. 2005; Hillyer 2005; Hoover et al., 2004; Obermeyer et al. 2005; Rice and Oleson 2004; Rice and Oleson 2005; Wright 2005). Moreover, Bt hybrids were more consistent in protecting corn roots compared to standard insecticides (Estes et al. 2004; Estes et al. 2005; Rice and Oleson 2004; Rice and Oleson 2005). Several researchers have also reported superior yields with YieldGard RW compared to the isolines treated with insecticides (Eisley 2004; Estes et al. 2004; Estes et al. 2005; Lauer 2004; Rice 2004; Rice and Oleson 2004; Rice and Oleson 2005). Overall, corn growers realized significant agronomic and economic benefits from planting YieldGard RW in 2005, similar to 2003 and 2004.

Yield experience with YieldGard RW is limited to only 2 commercial seasons thus far. Most of the field research with YieldGard RW corn hybrids focused mainly on root injury. Recently, comprehensive information began to emerge on the yield impacts of YieldGard RW. A three-year summary of corn rootworm control products in Iowa indicated that YieldGard RW hybrids averaged 1176 – 1848 pounds or 18% higher yields compared to the insecticide treatments (Rice and Oleson 2005). Based on the average corn yield of 9688 lb/acre in Iowa in 2005, this represents enhanced corn production of 12 – 19% due to YieldGard RW. Multi-year multi-location studies in Illinois also revealed that YieldGard RW corn hybrids out-yielded conventional insecticide treatments. Yield improvement due to the planting of YieldGard RW corn hybrids in Illinois was 26% in 2005 and 4 – 8% in 2004. Similar trends were also noted in Indiana (Krupke 2006).

Since crop yield is a function of several parameters and corn productivity is highest in the Corn Belt (average crop yields are lower in other states), a 5% improvement in yield was assumed due to YieldGard RW corn hybrids in 2005 for analytical purposes. In reality, the 5% yield gain due to YieldGard RW corn is a conservative estimate.

Table 8.2 displays information on changes in crop production and production value due to YieldGard RW corn. Based on 5% gain in per acre yields due to YieldGard RW hybrids, corn production was improved by 1.47 billion pounds in 2005. The value of this gained production was $52 million dollars.

Corn growers use both seed treatments (insecticides such as thiamethoxam and clothianidin at 1.25 mg ai/seed each) and soil insecticides (bifenthrin, carbofuran, chlorethoxyfos, chlorpyriphos, ethoprop, fipronil, phorate, tefluthrin , terbufos, and tebupirimphos + cyfluthrin) for corn rootworm larval control in conventional corn. Seed treatments for rootworm control are a relatively new technology (first marketed in 1999). The insecticides most commonly applied for control of corn rootworm larvae are chlorethoxyfos, chlorpyriphos, terbufos, tebupirimphos + cyfluthrin, bifenthrin, fipronil, and tefluthrin.

A survey of corn entomologists indicated that on average growers applied 0.51lb ai/A of insecticides at a cost of $15/A in 2005 (Krupke 2006; Larson 2005; Parker 2005; Rice 2006; Steffey 2006; Wildie 2005). Based on this assumption, it was calculated that growers that planted YieldGard RW corn hybrids in 2005 have applied 1.82 million fewer pounds of insecticides (Table 8.3).

YieldGard RW corn growers spent an average $14 per acre in 2005 to gain access to YieldGard RW corn hybrids (Krupke 2006; Rice 2006; Steffey 2006). Therefore, adoption costs, based on 3.5 million acres of planted acreage of Bt corn, were $49.0 million. However, net economic gain, due to increase in crop production and decrease in insecticide use and spray applications, was $55 million.

In spite of the use of YieldGard RW corn hybrids, insecticide treatments may still be needed to lessen the risk of damage caused by secondary pests such as wireworms, white grubs, flea beetles, and seed corn maggots, especially if their frequency of occurrence increase. This may either be in the form of current soil insecticides applied at planting, or in the form of an insecticide treatment coating on the seed. Monsanto requires seed companies to treat YieldGard RW corn seed with an insecticide for the control of secondary pests. While imidacloprid was used as seed treatment for YieldGard RW in 2003, thiamethoxam and clothianidin have been used since 2004. Thiamethoxam controls wireworms, white grubs, seed corn maggots and early flea beetles, while clothianidin controls all the above pests as well as black cutworm. The convenience of having soil insect protection in and on the seed without having to apply a soil insecticide at planting for secondary pest control is another reason for the increased adoption of YieldGard RW corn hybrids in 2005.

A second rootworm-resistant Bt corn that was available for commercial planting in 2006 was Herculex RW. The Herculex RW trait, developed jointly by Dow AgroSciences and Pioneer Hi-Bred International Inc., received full approval from U.S. regulatory agencies in October 2005. Herculex RW provides built-in protection against northern corn rootworm, western corn rootworm and Mexican corn rootworm. The Herculex RW trait is stacked with Herculex I to combine the protection against rootworm and corn borer, fall armyworm, black cutworm, and western bean cutworm and is available under the trade name Herculex XTRA. Both Herculex RW and Herculex XTRA were available during the 2006-planting season.

A third choice for corn rootworm management, MIR604, received registration approval from the US Environmental Protection Agency in October 2006 (Syngenta

2006). The modified full length Cry3Aa gene from *Bacillus thuringiensis* in MIR604 extends the activity to Northern, Western, and Mexican rootworms. Developed by Syngenta, the trait will be marketed as Agrisure RW during the 2007 crop season. Agrisure RW will be available as both single and stacked trait (with glyphosate resistance) in 2007. Registration is pending for the Agrisure RW trait stacked with corn borer resistance which would enable the commercialization of a triple stack product (resistance to rootworm/corn borer/glyphosate) in the coming years.

Table 8.1. Adoption of YieldGard RW corn in 2005

State	Planted acres[1]	Adoption of YieldGard RW corn[2]	YieldGard RW corn acreage
	000A	%	000Acres
Colorado	1100	3	33
Delaware	160	9	14
Illinois	12100	6	726
Indiana	5900	6	354
Iowa	12800	6	768
Kansas	3650	3	110
Kentucky	1250	3	38
Maryland	470	1	5
Michigan	2250	2	45
Minnesota	7300	6	438
Missouri	3100	2	62
Nebraska	8500	3	255
New York	990	3	30
North Dakota	1410	2	28
Ohio	3450	1	35
Oklahoma	290	1	3
Pennsylvania	1350	2	27
South Dakota	4450	7	312
Tennessee	650	1	7
Texas	2050	3	62
Virginia	490	1	5
Wisconsin	3800	4	152
Total/Average	**77,510**	**5**	**3,509**
US total/average	**81,759**	**4**	**3,509**

[1]National Agricultural Statistics Service. 2005 Acreage
[2]YieldGard RW corn adoption information in the United States is based on Doane Marketing Research Inc.'s 2005 Corn Trait Data

Table 8.2. Impacts of YieldGard RW corn on crop yield and value in 2005

State	Corn yield in 2005	Yield gain due to YieldGard RW corn[1]		Value of gained production[2]	YieldGard RW corn acreage	Yield gain due to YieldGard RW corn	Value of gained production from Bt acreage
	Bu/A	Bu/A	Lb/A	$/A	Acres	000Lb	000$
Colorado	135	6.8	381	13.34	33	12573	440
Delaware	137	6.9	386	13.51	14	5404	189
Illinois	145	7.3	409	14.32	726	296934	10396
Indiana	149	7.5	420	14.70	354	148680	5204
Iowa	173	8.7	487	17.04	768	374016	13087
Kansas	130	6.5	364	12.74	110	40040	1401
Kentucky	127	6.4	358	12.53	38	13604	476
Maryland	140	7.0	392	13.72	5	1960	69
Michigan	139	7.0	392	13.72	45	17640	617
Minnesota	160	8.0	448	15.68	438	196224	6868
Missouri	105	5.3	297	10.40	62	18414	645
Nebraska	160	8.0	448	15.68	255	114240	3998
New York	117	5.9	330	11.55	30	9900	347
North Dakota	120	6.0	336	11.76	28	9408	329
Ohio	141	7.1	398	13.93	35	13930	488
Oklahoma	135	6.8	381	13.34	3	1143	40
Pennsylvania	123	6.2	347	12.15	27	9369	328
South Dakota	118	5.9	330	11.55	312	102960	3604
Tennessee	130	6.5	364	12.74	7	2548	89
Texas	120	6.0	336	11.76	62	20832	729
Virginia	124	6.2	347	12.15	5	1735	61
Wisconsin	138	6.9	386	13.51	152	58672	2054
Total/Average	**135**	**6.8**	**379**	**13.26**	**3,509**	**1,470,226**	**51,459**

[1]A 5% yield gain was assumed due to the planting of YieldGard RW corn
[2]Approximate selling price of corn in 2005 = $1.95/bushel or 3.5 cents/lb

Table 8.3. Overall impacts of YieldGard RW corn in 2005

State	YieldGard RW corn acres	Gain in crop yield[1]	Gain in crop value[1]	Adoption costs[2]	Reduction in insecticide costs[3]	Net economic impact	Reduction in insecticide use[4]
	000 Acres	000Lb	000$	000$	000$	000$	lb ai/yr
Colorado	33	12573	440	462	495	473	16830
Delaware	14	5404	189	196	210	203	7140
Illinois	726	296934	10396	10164	10890	11122	370260
Indiana	354	148680	5204	4956	5310	5558	180540
Iowa	768	374016	13087	10752	11520	13854	391680
Kansas	110	40040	1401	1540	1650	1511	56100
Kentucky	38	13604	476	532	570	514	19380
Maryland	5	1960	69	70	75	74	2550
Michigan	45	17640	617	630	675	662	22950
Minnesota	438	196224	6868	6132	6570	7306	223380
Missouri	62	18414	645	868	930	707	31620
Nebraska	255	114240	3998	3570	3825	4253	130050
New York	30	9900	347	420	450	377	15300
North Dakota	28	9408	329	392	420	357	14280
Ohio	35	13930	488	490	525	523	17850
Oklahoma	3	1143	40	42	45	43	1530
Pennsylvania	27	9369	328	378	405	355	13770
South Dakota	312	102960	3604	4368	4680	3916	159120
Tennessee	7	2548	89	98	105	96	35700
Texas	62	20832	729	868	930	791	31620
Virginia	5	1735	61	70	75	66	2550
Wisconsin	152	58672	2054	2128	2280	2206	77520
Total	**3,509**	**1,470,226**	**51,459**	**49,126**	**52,635**	**54,968**	**1,821,720**

[1]Calculations on crop yield and value were detailed in Table 8.2.
[2]Adoption costs for YieldGard RW corn in 2005 = $14/A.
[3]Average cost of insecticides used for rootworm control in 2005 = $15/A.
[4]Average insecticide use rate for rootworm control = 0.51 lb ai/A.

References

Cullen, E., S. Chapman, and B. Jensen. UW Corn Rootworm Insecticide Efficacy Trials (2003,2004): Soil applied insecticide, insecticidal seed treatments, and transgenic Bt rootworm hybrids. Online Publication. Available at http://ipcm.wisc.edu/ wcm/pdfs/ 2004/Cullen1DecColleen.pdf

Doane's Marketing Research, Inc. (DMR). 2005. 2005 Corn Trait Data.

Eisley, B. 2004. Evaluation of YieldGard corn rootworm technology for control of corn rootworm larvae, 2004. Available at http://bugs.osu.edu/ag/reports/04ygrw. pdf - search='eisley%20rootworm%20corn'

Estes, R. E., J.B. Schroeder, K. L. Steffey, and M. E. Gray. 2004. Evaluation of products to manage corn rootworm larvae *(Diabrotica spp.)* in Illinois, 2004. Available at http://www.ipm.uiuc.edu/ontarget.

Estes, R. E., J.B. Schroeder, K. L. Steffey, and M. E. Gray. 2005. Evaluation of products to control corn rootworm larvae *(Diabrotica spp.)* in Illinois, 2005. Available at http://www.ipm.uiuc.edu/ontarget.

Haines, L. European Commission Approves Monsanto Genetically Modified Maize. The Register. August 10, 2005. Online Publication. Available at http://www. theregister.co.uk/2005/08/10/gm_maize_approved/.

Hoover, R., D. Calvin, G. Roth, C. Altemose, D. Johnson, M. Madden, B. Sullivan, T. Murphy, and J. Rowehl. 2004. Evaluation of transgenic Bt corn for rootworm control on Pennsylvania farms during 2003. Available at http://cornandsoybeans. psu.edu/ CMRR/ cmrr04_02.html.

Krupke, C. H. Purdue University. Personal Communication. 2006.

Larson, E. Mississippi State University. Personal communication. 2005.

Lauer, J. 2004. 2003 performance of Bt-CRW in university trials. Wisconsin Crop Manager. 11:14-15.

National Agricultural Statistics Service. 2005 Acreage. Available at http://www.usda. gov/nass.

Obermeyer, J., C.H. Krupke, and L. Bledsoe. 2005. Rootworm soil insecticides: choices, considerations, and efficacy results. Available at http://www.entm.purdue.edu/ entomology/ext/targets/newslett.htm.

Parker, R. Texas A and M University. Personal communication. 2005.

Rice, M. E. Iowa State University. Personal Communication. 2006.

Rice, M. E. 2004. Transgenic rootworm corn: assessing potential agronomic, economic, and environmental benefits. Plant Health Progress. March 2004 online publication.

Rice, M. E. 2005. Three-year summary of corn rootworm control products. Available at http://www.ipm.iastate.edu/ipm/icm/2005/12-12/rootworm.htm.

Rice, M. and J. Oleson. 2004. Two-year summary of corn rootworm insecticides and YieldGard Rootworm. Available at http://www.ipm.iastate.edu/ipm/icm/2004/11-15-2004/insecticidesummary.html.

Steffey, K. L. University of Illinois. Personal Communication. 2006.

Syngenta. 2006. EPA approves Agrisure RW corn trait. Available at http://www. syngenta-us.com/media/article.asp?article_id=694

Wildie, J. Kansas State University. Personal communication. 2005.

Wright, R. 2005. Corn rootworm efficacy trial results reported. Available at http://cropwatch.unl.edu/archives/2005/crop05-23.htm

9. Bollgard cotton (IR-III)

Bollgard cotton was planted on about 7.78 million acres of cotton acreage in 2005 (Table 9.1). On percent basis, this represented approximately 55% of the total planted cotton acreage. Adoption varied from a low of 6% in California to a high of 95% in Tennessee. Adoption of Bollgard cotton was highest in Tennessee (95%) followed by Louisiana (93%), Mississippi (88%), and Georgia (88%). Bollgard cotton adoption was lowest in California (8%) due to the lower incidence of Bollgard target pests (lepidopteran pests). Only 4% of the total planted California cotton acreage was infested with Bollgard target pests in 2005 (Williams 2005). Bollgard cotton adoption in Texas increased by 19% in 2005 compared to 2004 due to a rise in the level of pink bollworm infestations in the 2004-growing season.

Bollworm and budworm pest complex was ranked as number one pest problem in US cotton in 2005, similar to years before. Of the total crop loss of 4.5% due to cotton insect pests in 2005, bollworm/budworm complex accounted for one-third (Williams 2005). Cotton production losses due to arthropod pests were lower since 1996 compared to years before the commercialization of Bt varieties (Williams 2005). Increased use of Bollgard cotton was credited to have lowered the impact and aggregate losses due to arthropod pests in 2005, similar to years before. Bollgard cotton provided growers with an improved and reliable method to control bollworms and budworms.

Mullins et al. (2005) assessed the agronomic and economic advantage of Bollgard cotton in comparison with conventional cotton, based on large-scale university field trials in various cotton producing states. Assessments included insect control costs, number of insecticide applications, lint yields (volume and value), end-of-season boll damage levels, gross income, and changes in net revenue. Analysis indicated that Bollgard cotton growers have reduced per acre insecticide sprays by 0.93 applications, insecticide costs by $14.76; improved per acre lint yields by 81 lb, and net returns by $40.87 compared with conventional cotton (Mullins et al. 2005). The above stated estimates served as the basis for the impact assessment of Bollgard cotton in this report. Per-acre estimates were used to calculate aggregate impact estimates for each state. Adoption costs of Bollgard cotton were calculated based on Williams (2006) and are presented in Table 9.2. Aggregate impacts of Bollgard cotton are presented in Table 9.3.

Analysis indicated that Bollgard cotton plantings were associated with significantly higher lint yields and lower pesticide use in all the cotton producing states in 2005 (Table 9.3). In aggregate, Bollgard cotton produced 630 million more pounds of cotton lint valued at $271 million. In spite of increased lint production due to the planting of Bollgard varieties, value of gained production was lower in 2005 ($271 million) compared to 2004 ($337 million). This is mainly due to lower per pound lint price in 2005 ($0.43) compared with 2004 ($0.60).

Bollgard cotton production costs were reduced by $115 million in 2005 due to a reduction in the number of spray applications and overall insecticide use. Insecticide use in Bollgard cotton was reduced by 1.95 million pounds compared to conventional cotton. Averaged across various cotton growing states, insecticide applications were reduced by at least one, which translated to time, labor, and energy savings for cotton growers. Overall, net grower benefits due to Bollgard planting in 2005 amounted to $234 million. As stated above, economic advantage due to Bollgard cotton dropped 18% in 2005 ($234 million) compared to 2004 ($284 million) due to lower lint prices in 2005 compared to the year before.

The introduction of Bollgard cotton reduced the number of insecticide applications targeted towards lepidopteran pests. However, some insecticide applications are still required to suppress bollworms. Despite its proven usefulness as an important pest management tool, the need for supplemental remedial insecticide applications to fully control pests has been a minor drawback for Bollgard cotton. Bollgard cotton is extremely effective against tobacco budworm and pink bollworm but provides only suppression of cotton bollworm, loopers, armyworms, and other minor lepidopteran cotton pests. As a result, growers may have to spray for these pest problems under certain circumstances, especially during bloom stage.

In 2005, 83% of US cotton crop was infested with bollworm/budworm complex of which 95% were bollworms (Williams 2005). Approximately 37% of the Bollgard cotton acreage was sprayed with insecticide applications to control bollworms in 2005 (Table 9.4; Williams 2006).

A second generation Bt cotton (Bollgard II) with enhanced resistance to key cotton pest problems was developed by Monsanto and was planted on a limited acreage since 2003. Evidence indicates that the end-of-season boll damage was significantly lower (333%) in Bollgard II compared with Bollgard cotton (Mullins 2005). Grower experiences suggest that Bollgard II cotton eliminated the need for additional insecticide sprays for bollworm control. The impact of Bollgard II on pest management in 2005 is presented in the next case study (Case Study 10).

Table 9.1. Adoption of Bollgard cotton in the US in 2005

State	Planted acreage[1]	Bollgard cotton adoption	
	000 Acres	% of total[2]	000 Acres
Alabama	550	77.99	429
Arizona	234	61.63	144
Arkansas	1,050	87.41	918
California	660	5.82	38
Florida	86	79.63	68
Georgia	1,220	87.63	1,069
Kansas	74	62.83	46
Louisiana	610	92.95	567
Mississippi	1,210	87.69	1,061
Missouri	440	83.29	366
New Mexico	68	31.39	21
North Carolina	815	82.02	668
Oklahoma	255	75.76	193
South Carolina	266	83.34	222
Tennessee	640	94.81	607
Texas	5,975	21.47	1,283
Virginia	93	83.55	78
Total/Average	**14,245**	**55**	**7,778**

National Agricultural Statistics Service: 2005 Acreage
[2]Based on the 2005 Cotton Planting Data from the US Agricultural Marketing Service

Table 9.2. Adoption costs for Bollgard cotton in the United States in 2005

State	Planted Bollgard cotton acreage[1]	Bollgard cotton seed costs	
	000 Acres	$/acre[1]	000 $
Alabama	429	22	9438
Arizona	144	34	4896
Arkansas	918	25	22950
California	38	9	342
Florida	68	24	1632
Georgia	1,069	19	20311
Kansas	46	17	782
Louisiana	567	13	7371
Mississippi	1,061	22	23342
Missouri	366	17	6222
New Mexico	21	22	462
North Carolina	668	20	13360
Oklahoma	193	17	3281
South Carolina	222	19	4218
Tennessee	607	16	9712
Texas	1,283	17	21811
Virginia	78	22	1716
Total/Average	**7,778**	**20.0**	**151,846**

[1]Source: Williams 2006

Table 9.3. Aggregate impacts of Bollgard cotton in 2005[1]

State	Bollgard cotton adoption	Increase in cotton lint production	Increase in production value	Reduction in the number of insecticide sprays	Reduction in insecticide use	Reduction in insecticide and application costs	Adoption costs of Bollgard cotton[2]	Economic advantage due to Bollgard cotton
	000 Acres	000 lb	000$	000	000 lb	000$	000$	000$
AL	429	34749	14942	399	107	6332	9438	11836
AZ	144	11664	5016	134	36	2125	4896	2245
AR	918	74358	31974	854	230	13550	22950	22574
CA	38	3078	1324	35	10	561	342	1543
FL	68	5508	2368	63	17	1004	1632	1740
GA	1,069	86589	37233	994	267	15778	20311	32700
KS	46	3726	1602	43	12	679	782	1499
LA	567	45927	19749	527	142	8369	7371	20747
MS	1,061	85941	36955	987	265	15660	23342	29273
MO	366	29646	12748	340	92	5402	6222	11928
NM	21	1701	731	20	5	310	462	579
NC	668	54108	23266	621	167	9860	13360	19766
OK	193	15633	6722	179	48	2849	3281	6290
SC	222	17982	7732	206	56	3277	4218	6791
TN	607	49167	21142	565	152	8960	9712	20390
TX	1,283	103923	44687	1193	321	18937	21811	41813
VA	78	6318	2717	73	20	1151	1716	2152
Total	**7,778**	**630,018**	**270,908**	**7,233**	**1,947**	**114,804**	**151,846**	**233,866**

[1]Impacts were calculated based on Mullins et al., 2005. Accordingly, assessments, as compared to conventional non-Bt cotton, were as follows: reduction in total number of insecticide sprays in Bollgard cotton = 0.93; reduction in insecticide and application costs = $14.76/acre; gain in lint yields per acre = 81 lb; net economic advantage/acre = $40.87; average cost of 1 lb of cotton lint in 2005 = $0.43; insecticide use in conventional cotton was estimated to be 0.25 lb ai/A/application

[2]Based on Table 9.2

Table 9.4. Bollgard cotton acreage sprayed for bollworm control in 2005[1].

State	Bollworm applications to Bollgard cotton	Bollgard acreage sprayed for bollworm control
	#	Acres
AL	1.0	352,000
AZ	0.01	3,684
AR	1.4	631,500
CA	0.0	0
FL	1.0	3,400
GA	1.2	500,000
KS	0.0	0
LA	0.8	175,000
MS	1.0	617,737
MO	1.0	5,000
NM	1.0	2,700
NC	0.0	0
OK	1.0	11,778
SC	1.0	225,250
TN	1.1	105,000
TX	1.0	185,420
VA	0.9	16,740
Total	**0.96**	**2,835,209**

[1]Williams 2006

References

Mullins, W., D. Pitts, and B. Coots. 2005. Sisterline comparisons of Bollgard II versus Bollgard and non-Bt cottons. 2005 Beltwide Cotton Conferences. Pp. 1822 – 1824. Available at http://www.cotton.org/beltwide/proceedings/2006/search.html.

National Agricultural Statistics Service. 2005 Acreage. Available at www.usda.gov/nass.

National Agricultural Statistics Service. 2005 Agricultural prices. Available at www.usda.gov/nass.

United States Department of Agriculture – Agricultural Marketing Service. Cotton Varieties Planted, United States, 2005 crop. Available at www.ams.usda.gov/cotton/mncs/index.htm.

Williams, M. 2006. Cotton Insect Losses – 2005. Available at http://www.cotton.org/beltwide/proceedings/2006/pdfs/1151-1204.pdf

10. Bollgard II cotton (IR-IV)

Bollgard II cotton was planted on around 322,000 acres in the 2005 crop-season (Table 10.1). This represents 2.3% of the total planted cotton acreage and 4.0% of total Bt cotton acreage. Bollgard II cotton adoption increased by 66% in 2005 compared with 2004. Overall, Bollgard II adoption is lower than Bollgard as the trait is not available in enough number of cotton varieties suitable for various geographic locations (Turnipseed 2005).

The U.S. Environmental Protection Agency has granted an unconditional registration of the Bollgard II insect-protected cotton technology in September 2006. It is expected that there will be an expanded number of cotton varieties with Bollgard II and Roundup Ready Flex traits across the Cotton Belt during 2007.

In 2005, Bollgard II cotton was planted in all cotton producing states except California, Florida, Kansas, and Tennessee. Whereas percent acres planted to Bollgard II varieties was greatest in New Mexico (47%) followed by Arizona (7%), number of planted acres was highest in Texas followed by North Carolina (Table 10.1).

First available for planting since 2003, Bollgard II cotton is the second-generation of insect-resistant cotton developed by Monsanto. Bollgard II offers enhanced protection against cotton bollworm, fall armyworm, beet armyworm, and soybean looper while maintaining control of tobacco budworm and pink bollworm (similar to the protection provided by the Bollgard). Bollgard II contains two Bt genes, Cry1Ac and Cry2Ab, as opposed to the single gene (Cry1Ac) in its predecessor, Bollgard. The presence of two genes in Bollgard II provides cotton growers with a broader spectrum of insect control, enhanced control of certain pests, and increased defense against the development of insect resistance. The presence of the Cry2Ab gene in addition to the Cry1Ac in Bollgard II cotton provides a second, independent high insecticide dose against the key cotton pests. Therefore, Bollgard II is viewed as an important new element in the resistance management of cotton insect pests.

Multi-location large-plot field trials were conducted across the cotton-belt to assess the agronomic and yield performance of Bollgard II cotton in comparison with Bollgard and conventional cotton (Mullins et al. 2005). Research findings indicated that Bollgard II enhanced insecticidal activity against pests on which Bollgard was weakest.

The enhanced control with Bollgard II of the principal cotton bollworm/budworm complex and control of secondary lepidopteran insect pests (such as the armyworms and loopers) has resulted in increased yield and reduced insecticide use in the US in 2005, similar to 2004 and 2003.

Multi-location studies analyzed by Mullins et al. (2005) were the basis for the impact assessments of Bollgard II in this report. These studies have indicated that Bollgard II cotton averaged 0.47 fewer insecticide applications, 20 pounds more lint yields, and $10.76 more economic returns per acre compared to Bollgard cotton. In comparison to the conventional non-Bt cotton, Bollgard II cotton averaged 1.12 fewer insecticide applications, $16.88 less insecticide costs, 128 pounds more lint yields, and $70.52 higher economic returns per acre. Impacts were analyzed based on the conclusions drawn from comparisons between Bollgard II and conventional (non-Bt) cotton. Estimates on insecticide use in Bollgard II cotton were made based on the National Center's 2002 report. Adoption costs were calculated based on Williams (2006) (Table 10.2).

Bollgard II cotton provided similar agronomic advantages as its predecessor, Bollgard. These benefits included improved insect control as reflected by increased yields, reduction in input costs, reduced pesticide use, and number of spray applications (Table 10.3). However, yield improvement and pesticide use reduction, as noted above, is higher with Bollgard II compared to Bollgard (Mullins et al. 2005).

Based on the per acre impacts listed above, it is estimated that Bollgard II improved US cotton lint production by 41.4 million pounds, the value of which was $17.8 million in 2005. (Table 10.2). Cotton growers made 0.4 million fewer trips across the field, which represent significant labor, time and fuel savings in addition to reduced equipment wear and tear. The reduction in insecticide use of 0.24 million pounds led to $5.5 million savings on insecticide costs. The economic advantage of Bollgard II cotton in 2005 was $70.5 and $10.8 per acre compared with conventional and Bollgard cotton, respectively (Mullins et al. 2004). Net grower returns due to the planting of Bollgard II cotton in 2005 were $16.8 million.

Using a strategy similar to Bollgard II, Dow Agrosciences developed 'WideStrike' cotton to simultaneously express two separate insecticidal Bt proteins, Cry1Ac and Cry1F. Similar to Bollgard II, the WideStrike cotton offers season-long protection against a broad-spectrum of cotton pests such as cotton bollworm, tobacco budworm, pink bollworm, beet armyworm, fall armyworm, yellow-striped armyworm, cabbage looper and soybean looper (Dow Agrosciences 2003). WideStrike cotton received deregulatory status from USDA, full registration from EPA and completed pre-market consultations with FDA during 2004 (Agserv 2003; Richardson et al. 2003).

WideStrike cotton was planted for the first time during the 2005 crop season. Only three states, Arizona, Texas, and Virginia, planted the WideStrike cotton during the introductory year. Together, the above-mentioned three states planted a total of about 26,000 acres to this new cotton trait (Table 10.4). This represents about 0.16% adoption across the United States. Research conducted in various states of the Cotton Belt suggests that the performance and efficacy of WideStrike cotton in controlling bollworm/budworm complex was similar to Bollgard II in 2005 (Jackson et al. 2006, Lorenz et al., 2006; Mickinski et al. 2006).

Impacts were not assessed for WideStrike cotton in this report in view of its low acreage in its introductory year and also due to the lack of robust yield data. WideStrike trait was available in only few varieties (PHY 440W; PHY 470WR; PHY 480WR) in 2005 (USDA-AMS). The trait will be available in more and better performing varieties in the next few years. It is anticipated that a total of 6 varieties (PHY 370WR; PHY 440W; PHY 470WR; PHY 480WR; PHY 485WRF; NM 1517-99WR) will be available to growers in 2006 (Haygood et al. 2006).

Another Bt cotton that is expected to be available for cotton growers in the near future is ‘VipCot’ developed by Syngenta. VipCot contains a vegetative insecticidal protein (Vip) derived from the *Bacillus thuringiensis* bacterium (Syngenta 2003). Field tests have indicated that Vip protein provides broad spectrum, full season control of major lepidopteran and spodopteran pests. Vip protein also protects the entire plant, including the flowering parts. Unlike Bt cotton, which is an endotoxin, Vip protein, is an exotoxin and thus differs structurally, functionally, and biochemically from Cry protein. As a result, the mode of action of Vip protein is different than Cry protein. In August 2004, Syngenta entered into a cooperative agreement with Delta and Pine Land Company to develop and register VipCot (Negrotto and Martin 2005). VipCot may be commercially available in 1 to 2 years. The availability of WideStrike and VipCot along with Bollgard II could aid in bolstering insect resistance management in cotton due to their diverse modes of action in addition to providing growers with a wide choice of pest management tools.

Table 10.1. Adoption of Bollgard II cotton in the United States in 2005

State	Planted acreage[1]	Bollgard II adoption[2]	
	000 Acres	%	Acres
Alabama	550	0.08	440
Arizona	234	7.34	17176
Arkansas	1,050	0.33	3465
California	660	0	0
Florida	86	0	0
Georgia	1,220	0.26	3172
Kansas	74	0	0
Louisiana	610	0.12	732
Mississippi	1,210	0.14	1694
Missouri	440	2.46	10824
New Mexico	68	46.5	31620
North Carolina	815	5.17	42136
Oklahoma	255	4.38	11169
South Carolina	266	3.11	8273
Tennessee	640	0	0
Texas	5,975	3.22	192395
Virginia	93	0	0
Total/Average	**14,245**	**2.26**	**321,937**

[1] National Agricultural Statistics Service: 2005 Acreage
[2] Based on the 2005 Cotton Planting Data from the US Agricultural Marketing Service

Table 10.2. Adoption costs for Bollgard II cotton in the United States in 2005

State	Planted Bollgard II cotton acreage	Bollgard II cotton seed costs	
	Acres	$/acre	000$
Alabama	440	23	10
Arizona	17176	35	601
Arkansas	3465	26	90
Georgia	3172	20	63
Louisiana	732	14	10
Mississippi	1694	23	39
Missouri	10824	18	195
New Mexico	31620	23	727
North Carolina	42136	21	885
Oklahoma	11169	18	201
South Carolina	8273	20	165
Texas	192395	18	3463
Total/Average	**321,937**	**22**	**6,449**

Source: Williams, 2006.

Table 10.3. Aggregate impacts of Bollgard II cotton in 2005[1]

State	Bollgard II cotton adoption	Increase in cotton lint production	Increase in production value	Reduction in the number of insecticide sprays	Reduction in insecticide use	Reduction in insecticide costs	Adoption costs of Bollgard II cotton[2]	Net economic advantage
	Acres	000 lb	000$	#	000 lb	000$	000$	000$
AL	440	56	24	493	0.332	7	10	22
AZ	17176	2199	945	19237	12.951	290	601	634
AR	3465	444	191	3881	2.613	59	90	159
GA	3172	406	175	3553	2.392	54	63	165
LA	732	94	40	820	0.552	12	10	42
MS	1694	217	93	1897	1.277	29	39	83
MO	10824	1386	596	12123	8.161	183	195	584
NM	31620	4047	1740	35414	23.841	534	727	1547
NC	42136	5393	2319	47192	31.771	711	885	2146
OK	11169	1430	615	12509	8.421	189	201	602
SC	8273	1059	455	9266	6.238	140	165	430
TX	192395	24627	10589	215482	145.066	3248	3463	10374
Total	**321,937**	**41,358**	**17,782**	**361,867**	**243.615**	**5,456**	**6,449**	**16,788**

[1]Impacts were calculated based on Mullins et al., 2005. Accordingly, assessments, as compared to conventional non-Bt cotton, were as follows: reduction in total number of insecticide sprays due to Bollgard II cotton = 1.12/acre; reduction in insecticide and spray costs = $16.88/acre; gain in lint yields per acre = 128 lb; net economic advantage/acre = $70.52; cost of 1 lb of cotton lint in 2005 = $0.43; average insecticide use in conventional cotton was estimated to be 0.25 and 0.423 lb ai/A for bollworm/budworm and armyworms/soybean loopers, respectively

[2]Based on Table 10.2

Table 10.4. Adoption of WideStrike cotton in the United States in 2005

State	Planted acreage[1]	WideStrike adoption[2]	
	000 Acres	%	Acres
Arizona	234	0.18	421
Texas	5,975	0.43	25693
Virginia	93	0.13	121
Total/average	**6302**	**0.42**	**26,235**
US total/average	**14,245**	**0.16**	**26,235**

[1] National Agricultural Statistics Service: 2005 Acreage

[2] Based on the 2005 Cotton Planting Data from the US Agricultural Marketing Service

References

AgServ (Economic forecast by Doane Agricultural Services). 2004. USDA deregulates WideStrike insect protection. Available at http://www.agserv.com/show_story .php?id=26375.

Dow AgroSciences. 2003. Dow AgroSciences receives Experimental Use Permit for WideStrike insect protection. Available at www.phytogenyields.com/usag/ resource/20030423a.htm.

Haygood, R. A., L. B. Braxton, R. M. Huckaba, R. B. Lassiter, A. R. Parker, J. M. Richardson, J. S. Richburg, G. D. Thompson, L. C. Walton, F. J. Haile, and M. W. Siebert. 2006. Performance of PHY 410R and PHY 470 WR expressing the WideStrike insect protection trait in 2005 strip trails. 2006 Beltwide Cotton Conferences. Pp. 1549 -1551.

Jackson, R. E., S. Malone, J. R. Bradley, J. Van Duyn, A. Herbert, and R. M. Huckaba. 2006. Efficacy of WideStrike and Bollgard II cottons against bollworm under insecticide-sprayed and non-sprayed conditions in North Carolina and Virginia. 2006 Beltwide Cotton Conferences. Pp. 1531-1535.

Lorenz, G. M., K. Colwell, R. B. Lassiter, J. Greene, G. Studebaker, J. Hardke, and C. Shelton. 2006. Performance of WideStrike cotton in Arkansas, 2004 – 2005. 2006 Beltwide Cotton Conferences. Pp. 1526-1530.

Mickinski, S., W. F. Waltman, and H. L. Spaulding. 2006. Efficacy of WideStrike for the control of the bollworm/tobacco budworm complex in Northeast Louisiana. 2006 Beltwide Cotton Conferences. Pp. 1090-1094.

Mullins, W., D. Pitts, and B. Coots. 2005. Sister-line comparisons of Bollgard II versus Bollgard and Non-Bt cottons. 2005 Beltwide Cotton Conferences. Pp. 1822-1824.

National Agricultural Statistics Service. 2005 Acreage. Available at www.usda.gov/ nass.

National Agricultural Statistics Service. 2005 Agricultural prices. Available at www.usda.gov/nass.

Negrotto, D., and T. Martin. 2005. VipCot progress update. 2005 Beltwide Cotton Conferences. Pp. 1497.

Richardson, J., L. Braxton, and J. Pellow. 2005. Field efficacy of WideStrike insect protection against pink bollworm. 2005 Beltwide Cotton Conferences. Pp 1446-1447.

Syngenta. 2003. Syngenta plans to introduce a new choice for transgenic control of worms in cotton. Media highlights. Available at www. http://www.syngentacrop protection-us.com/media/article.asp?article_id=303.

Turnipseed, S. Clemson University. Personal communication. 2005.

United States Department of Agriculture – Agricultural Marketing Service. Cotton Varieties Planted, United States, 2005 crop. Available at www.ams.usda.gov/ cotton/mncs/index.htm.

Williams, M. 2006. Mississippi State University. Personal communication.

Conclusion

Every crop management decision has consequences, and the decision to plant biotechnology-derived crops is no exception. American growers have made the decision to choose biotechnology-derived crops for the last 10 years because they realized significant and positive benefits from planting these crops. In addition to revolutionizing the way crops are produced, biotechnology provided best hope to growers by providing enhanced pest protection thereby improving yields with the use of minimal inputs. With that increased hope and confidence, American growers have increased the planting of biotechnology-derived crops from 5 million acres in 1996 (the first year of commercial planting) to 123 million acres in 2005 (the tenth year of commercial planting). The fact that adoption of biotechnology-derived crops has continued to grow each year since their first introduction is a testimony to the ability of these crops to deliver tangible positive impacts and to the optimistic future they hold.

American growers' confidence in biotechnology-derived crops, as reflected in the increased adoption each year, is due to the positive impacts provided by these crops in the form of enhanced crop yields, improved insurance against pest problems, reduced pest management costs, lowered pesticide use, and overall increase in grower returns. While control of key insect pests that resulted in increased yields and reduced insecticide use were the reasons for the success of Bt crops, simplicity and flexibility of weed management afforded by herbicide-resistant crops enhanced their adoption.

In spite of proven potential and documented positive impacts, opponents continue to argue about impacts of these crops on environmental safety and human health. Several researchers have concluded that biotechnology-derived crops are as safe as, if not safer, than their conventional counterparts. Other concerns such as pest-resistance and gene flow are not only akin to biotechnology-derived crops, but relate to conventional pest management practices as well.

Biotechnology-derived crops in production to date in the United States have modified crop protection characteristics only. The second generation of biotechnology-derived crops is already underway and includes traits that may solve production challenges such as cold-tolerance, drought-tolerance and increased nitrogen efficiency and output traits such as better flavor and appearance, greater shelf life, and improved nutritive value. New biotechnology-derived crops in development such as drought-tolerant corn are currently being field-tested and are presenting potential production and income growth opportunities with improved yields of 9 to 14% (as noted in preliminary trials). With a pipeline that is packed with crops that may further improve yields and deliver health and safety benefits to consumers, public approval for these crops will continue to only increase in the near future.