Quantification of the Impacts on US Agriculture of Biotechnology-Derived Crops Planted in 2006

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Table of Contents

Introduction

The adoption of biotechnology-derived crop varieties continues to be rapid and encompasses all areas in the US. Planted acreage to these crop varieties was 252 million acres in 2006, up from 222 million acres in 2005. This is the initial year in the second decade of the commercial availability of biotechnology-derived crop varieties. The crop varieties are expanding in several ways worth mentioning. First, the varieties are being adapted to different locations and climatic zones so that producers have better choices of biotechnology-derived crops. Second, there is an expansion of the traits that the biotechnology-derived crops encompass, mostly related to insect pests. Finally, there is an increasing tendency to "stack" the traits, i.e. in a single variety including Roundup Ready weed control and insect control traits related to rootworms and bollworms.

World wide the evidence of the changes to the biotechnology-derived crops is evident as well (James 2060). Numerous countries have adopted the biotechnology-derived varieties. These include both developed and developing nations. Thus, while there is understandable hesitancy in selected countries, the biotechnology-derived crop revolution is occurring. The yield and cost differences that we have documented for the US are the reason. Growers can obtain significant benefits from adopting the biotechnology-derived crops.

The US continues to lead the world in plantings of biotechnology-derived crops. Comparing 2005 to 2006, we see that for the herbicide-resistant crops the gains were not strong. This is because the herbicide resistant crops planted as a proportion of total acreage were near the total planted acreage, due to saturation of the available market. This is not the case with the insecticide resistant crops. Here the industry is newer and not all situations have varieties suitable to the local areas been identified. Following are the results for 2005 and 2006:

	2005		**2006**	
	Total HR acreage	% Total HR acres	Total HR acreage	% Total HR acres
Papaya (VR)	1,320	55	1,926	90
Squash (VR)	6,755	17	7,956	22
Canola (HR)	1,060,000	93	952,000	87
Corn (HR)	27,929,000	35	41,020,000	53
Cotton (HR)	11,128,000	79.9	13,195,000	86.4
Soybean (HR)	64,630,000	88	67,739,000	90
Corn (YieldGard Corn Borer)	27,911,572	34	16,602,689	21
Corn (YieldGard RW)	3,509,000	4	7,688,000	9.7
Cotton (BollGard)	7,778,000	55	7,464,000	49
Cotton (BollGard II)	321,937	2.26	1,337,345	15

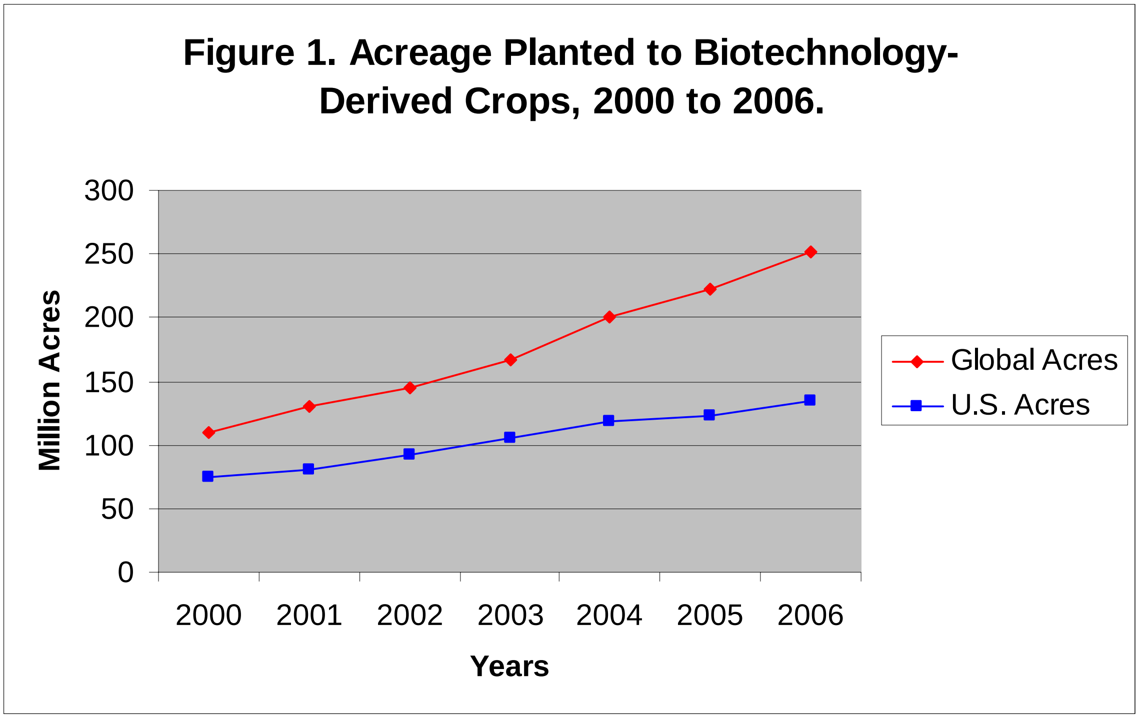
It is important to observe that these numbers were gathered in many cases from extension or research crop specialists in the states. Thus, there is some anticipated error in these judgmental figures. In addition, there is stacking, particularly for the insect resistant cultivars which may have influenced the recording by variety.

The report this year was completed by a different set of authors due to the evolution of the National Center for Food and Agricultural Policy. Since 2001, the authors were Gianessi 2002, Sankula and Blumenthal 2003, Sankula and Blumenthal 2004, Sankula 2005 and this report by Johnson and Strom. Our report took somewhat longer to complete than earlier reports, because the crew of writers and researchers were different. The previous authors were extremely helpful and we appreciate their assistance. There was much for us to do through discovery of new data, as well as making new contacts with extension and university crop specialists.

Change continues in the biotechnology-derived crops and these changes may make it more difficult to complete reports like this. The stacking of traits in crop varieties is likely the one that will make it most difficult. In fact, each of the stacked alternatives is a different crop variety. The way to keep each of the traits is to record all of the combinations of traits that are available to growers. This will make for more case studies since the stacking will require added numbers of trait “packages.” We acquired and used the Doane Corn TraitTrak Data which gives more extensive data in terms of packages than that obtained from crop specialists in the states.

New biotechnology-derived crops are coming into the market as well. These are largely insecticide resistant varieties and address some of the second order problems with biotechnology-derived crops. Examples include the other worms for corn than rootworm, as well as the ability to use the insecticide near the harvest period. In the latter case the impact is to introduce flexibility and in the other the impact to further reduce the loss from pests.

In short, the biotechnology-derived crops represent a moving target and will continue in this manner for the near future.



Area of Biotech Crops
1996 to 2006

Year	Global Acres	U.S. Acres
2000	109.2	74.9
2001	130	80
2002	145	92
2003	167.2	106
2004	200	118
2005	222	123
2006	252	134.9

[1]Clive James 2006, as shown in ISAAA Bried 35-2066: Slides & Tables, www.isaaa.org/.
[2]National Agriculture Statistics Service, Acreage, www.nass.usda.gov.

Method

The objective of this report is to evaluate and quantify the impacts on US agriculture of biotechnology-derived crop cultivars planted in the eleventh year of commercial cultivation. Table 1 depicts the trait information for eight biotechnology-derived crops (alfalfa, corn, cotton, canola, papaya, squash, soybean and sweet corn) planted in 2006. Impacts were analyzed for only six of these crops (corn, cotton, canola, papaya, squash and soybean). Impacts were not analyzed for alfalfa and sweet corn, due to limited acreage planted in 2006. The year 2006 will be the first year of planting of biotechnology-derived cultivars for alfalfa.

Information was analyzed and updated for ten case studies (Table 2). Although there were only six planted biotechnology-derived crops, for some crops, corn and cotton, more than one pest management trait in commercial production was managed by the biotechnology-derived cultivars. The number of case studies (10) was the same as in 2005. The report does not detail the background information on each case study as the status of pest problems and conventional peat management practices have more or less remained unchanged since the earlier reports were released in 2002-2005. Background information for all case studies in this report can be found in earlier reports, which can be accessed at http://www.ncfap.org.whatwedo/40casestudies.php.

As already mentioned what did change this year and will be an even greater factor next year is the relative prices of crop inputs and outputs. Due to the increase in energy prices, fertilizer and fuel expenses have increased for all crops. This has a double effect because the same inputs are used in seed production, raising costs here as well. Balancing this increase in input costs was the increase in output prices. However, these were not anticipated at planting time, as were the prices of inputs. These trends will continue and be more predominant in 2007. And, they can cause changes in the adoption of biotechnology-derived seeds in crop production.

As in the case of the earlier reports, states for which pest management practices would be impacted due to the adoption of biotechnology-derived crop cultivars were identified and impacts were quantified. The states selected were in almost all cases the same as in 2005. For example, some case studies (e.g. virus-resistant squash and herbicide-resistant canola) only selected states were included in the analysis. For these crops only those states where the larger production occurred or where there was special interest of some kind were included. This had an effect on the geographical scope of the analysis.

The method used in this and past reports was the same - the effectiveness of the biotechnology-derived cultivars or crops in controlling the target pest(s), and calculating impacts on yield. Impacts were identified and quantified in four categories: changes in production volume, value, cost and pesticide used. As will be apparent from the tables presented, USDA/NASS data were very valuable as a resource in the determination of the above mentioned impacts.

Production volumes were measured based on yield changes that occurred when the biotechnology-derived crops replaced existing crop production practices. Changes in production costs were calculated by determining which of the current practices would be affected. Adoption costs associated with the use of technology (either as royalty technology fee or a seed premium or both) were considered in these calculations. Finally, changes in pesticide use were quantified when the biotechnology-derived crop cultivar had replaced or substituted for the current crop cultivar, and use levels of the targeted pesticides leading to either increased or decreased usage. All the above impacts were calculated using USDA/NASS acreage and other production information.

The key information for this report and those preceding it comes from university researchers and extension crop specialists who were surveyed to evaluate existing pest management approaches for conventional crops and to determine how the biotechnology-derived crops replaced or substituted for current practices. In fact, many of the cost, yield differential and differences in pesticide use come from crop budgets that are mostly prepared at on a state basis by these specialists. Pesticide use and pest-loss reports were also assembled. Updated estimates, in a case study format, were sent to relevant experts for comment. Results of these comments and suggestions were integrated into this report.

In addition to the specialists, others have kept consistent records of biotechnology crops and impacts. These are for cotton (Michael R. Williams, Cotton Insect Losses 2006, sponsored by the Cotton Foundation) and the Doane Corn TraitTrak Data (proprietary), which we recommend that interested readers consult additional information.

Table 2. Case studies for which impacts were analyzed for 2006 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).

References

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Virus-Resistant Crops

The two biotechnology-derived virus-resistant crops that were grown commercially in the US during 2006 were the same as those grown in 2005, papaya and squash. As will be apparent these crops are gaining in adoption in 2006 over 2005. The following two sections update the impacts based on their planted acreage on 2006.

1. Papaya

The number of acres on which biotechnology-derived virus resistant papaya was planted in 2006 continued to increase from 2005. The numbers presented are for Hawaii, which is the state that has the primary production in the US. Virus resistant papaya varieties are planted to approximately 90 percent of total acreage in 2006, up from 55 percent in 2005 (Table 1.1). Note that total acreage was down in 2006 compared to 2005. Thus what we had was a decline in acreage and an increase in biotechnology-derived cultivars. As will be apparent in the subsequent discussion, there are several reasons for this drop in production—one of which was the unavailability of seeds.

Similar to 2004 and 2005, Hawaiian growers planted three types of biotechnology-derived virus-resistant papaya varieties in 2006. These were “Rainbow”, “Sunup” and “Laie Gold.” Rainbow remained the most popular variety, accounting for 95 percent of the planted acreage. A comparison of Table 1.1 and Table 1.2 provides the basis for an interesting story. Planted acreage was 2140 in 2006 compared to 2400 in 2005. That is, total acreage was down by approximately 250 in 2006. However, the acreage planted to the virus-resistant varieties was 1926 in 2006 compared to 1320 in 2005, an increase in the virus-resistant varieties of 45 percent.

Yields were considerably lower in 2006 than 2005: 9.4 tons compared to 11.1 tons. The lower planted acreage and lower yields suggests a crop year that was stressful for the crop. As well, there was apparently a shortage of seeds for the traditional variety, again partly due to the poor growing conditions. There was such a short amount of the non-biotechnology varieties planted that yield comparisons were difficult to make. The experts suggested that that the yield differential was about the same in percent as 2005, 10-20 percent. We made the calculations in Table 1.2 in the assumption of a 15 percent yield increase for the biotechnology-derived varieties and values of the crop that were the same as in 2005. Note that even though acreage was down, there was increased value for the biotechnology-derived cultivars, $1,951,000 compared to $1,661,000.

Papaya growers had to pay for seed of the biotechnology-derived crop in 2006, similar to 2005. Since the discontinuation of the Papaya Administrative Committee (PACs) Federal Marketing Order in 2002, the Hawaii Papaya Industry Association has set the seed cost for biotechnology-derived varieties. Seed distribution costs for biotechnology-derived papaya were again set at $20 per ounce (Perry 2006). At normal seeding rates, growers planting biotechnology-derived seeds incurred about $100 per acre added costs. Based on conventional seed costs of $40 per acre, five ounces of seed at $8 per ounce (Uchidda 2006), it is estimated that the papaya growers paid a total of $100 less $40 or $60 times the total acres of biotechnology-derived crop or $173,340 to access the biotechnology-derived varieties in 2006. The value of production gained from planting the biotechnology-derived seeds was estimated at 15 percent times the yield per acre of 9.4 tons equals 5,274,000, as the increase in yield times the same price as in 2005 equals $1,951,000) That is, in 2006 the benefit over cost was approximately $1,750,000. Thus, the planting of biotechnology-derived seeds had a substantial payoff even in a year of down yields.

Again and even more than in 2005, there was a shift of acreage to biotechnology-derived cultivars—from 55 percent of planted acreage of 2400 to 90 percent of a lower planted acreage of 2140. Even with the lower acreage, there was an increase in acreage planted from 1320 to 1926, a very substantial increase.

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	3,205	37	1,186
2000	2,775	42	1,166
2001	2,720	37	1,006
2002	2,145	44	944
2003	2,380	46	1,095
2004	2,230	53	1,182
2005	2,400	55	1,320
2006	2,140	90	1,926

[1]Comprised of biotechnology-derived 'Rainbow', 'Sunup', and 'Laie Gold' varieties.
[2]Source: Hawaii Agricultural Statistics Service 2005 Yearbook, 1999-2005, National Agricultural Statistics Service, 2006.

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 lbs)	(%)	000lb	000$
1998	–	9.4	–	–	–
1999	1,186	10.9	16	3,558	1,174
2000	1,166	16.6	77	16,790	5,541
2001	1,006	14.1	50	9,456	3,121
2002	944	13.4	43	7,552	2,492
2003	1,095	13.5	44	8,979	2,963
2004	1,182	14.4	53	11,820	4,373
2005	1,320	11.1	18	4,488	1,661
2006	1,926	9.4	150	5,224	1,951
Cumulative Total				**62,643**	**21,325**

[1]Source:Hawaii Agricultural Statistics Service 1999-2005, National Agricultural Statistics Service, 2006.

[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).

[5]Reduced yield in 2006 is due to a shortage of biotechnology-derived papaya seed. Growers unable to get biotechnology-derived seed planted conventional seed that developed ring-spot disease reducing yields. Yields and value of production were adapted from the 2005 figures.

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2. Squash

Biotechnology-derived virus-resistant squash was not widely planted in 2006, but the increase was significant compared to earlier years, especially considering the increasing base. The total acreage for the seven states analyzed was approximately two thirds of the total US acreage, 42,000 acres compared to 60,700 acres. This year, 22 percent of this acreage was planted to virus-resistant varieties, or 7,956 compared to 6,755 acres in 2005 (Sankula, 2006). That is, even though low as a proportion of total US acreage, the total acreage planted was up more than 1,000 acres (Table 2.1).

As is apparent, the adoption of virus-resistant varieties varies greatly across states, from a high of 70 percent in New Jersey to a low of 5 percent in Michigan. The figure of 70 percent is a 45 percentage point increase from 2005 from 25 in 2005. Generally, the Southern states have the higher production levels in terms of acreage and adoption rates for the virus-resistant varieties which are about the same as in 2005 (see Table 2.2).

The cost comparisons are provided in Table 2.3. Added seed costs due to the biotechnology-derived virus-resistant squash compared to conventional squash as follows. Average costs of conventional seeds were $254 per 10,000 the standard seeding rate per acre. Bio-technology derived squash seeds were an average of $406 per acre (Marchese, 2007). Thus, assuming the same seeding rate per acre, the cost of the biotechnology-derived seed was $152 higher than the conventional seeds. Even with the higher costs, the farmers planted the biotechnology-derived seeds as a way of managing the possibility of losses in yield per acre.

Data on impacts of the biotechnology-derived seeds in terms of production value are provided in Table 2.3. These estimates are calculated as in the case of other crops. The yield differences were calculated from Table 2.1 and Table 2.2. It was assumed that the biotechnology-derived seeds were planted in areas where there were potentially serious virus infestation and that without the biotechnology-derived seeds there would have been a total loss. Using this assumption, the net gain over cost is estimated at $24.197 million dollars. The gain in yield is 78.4 million pounds.

These estimates are, if anything, probably high. The assumption of a total loss if the biotechnology-derives seeds were not planted may be excessive. But the virus when present more or less takes the entire field. The weakness in the assumption is that farmers may have planted the biotechnology-derived seed when not necessary. This would imply an upward bias in the estimates. However, from a decision making under uncertainty point of view, farmers gain if the alternative is to loose their entire crop.

Table 2.1. Acreage and production of U.S. squash in 2006.[1]

State	Area Planted	Production	Production Value
	Acres	Million lb	000$
Florida	10,500	102	38,760
Georgia	13,500	208	49,920
Michigan	8,700	176.4	14,994
New Jersey	2,900	2.5	7,600
North Carolina	4,300	41	11,480
South Carolina	1,400	10.4	3,120
Tennessee	1,100	8.6	1,725
Total	**42,400**	**548.9**	**127,599**
U.S. Total	**60,700**	**948.2**	**229,386**

[1]Source: National Agricultural Statistics Service, Vegetables 2006 Summary. California, New York, Ohio, Oregon and Texas have squash acreage; however, they were not included in this report.

Table 2.2. Adoption of biotechnology-derived virus-resistant squash varieties in 2006.

State	Area Planted	Adoption of virus-resistant squash	Acreage planted to virus-resistant squash	Source[1]
	Acres	% of total	Acres	
Florida	10,500	20	2,100	McAvoy
Georgia	13,500	20	2,700	Kelley
Michigan	8,700	5	435	Zandstra
New Jersey	2,900	70	2,030	Infante-Casella
North Carolina	4,300	7	301	Schultheis
South Carolina	1,400	20	280	Boyhan
Tennessee	1,100	10	110	Bost
Total/Average	**42,400**	**22**	**7,956**	
U.S. Total	**60,700**	**13**		

[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 2006.

State	Acreage planted to virus-resistant squash	Adoption costs[1]	Yield advantage[2]	Gain in value[2]	Net Gain
	Acres	$	Million lb	000$	000$
Florida	2,100	319,200	20.4	7,752	7,433
Georgia	2,700	410,400	41.6	9,984	9,574
Michigan	435	66,120	8.8	750	684
New Jersey	2,030	308,560	1.8	5,320	5,011
North Carolina	301	45,752	2.9	804	758
South Carolina	280	42,560	2.1	624	581
Tennessee	110	16,720	0.9	173	156
Total	**7,956**	**1,209,312**	**78.4**	**25,406**	**24,197**

[1]Adoption costs = added seed costs due to biotechnology-derived virus-resistant squash compared to congenital squash. Average costs of conventional and biotechnology-derived squash varieties were $406 and $254 for 10,000 seeds per acre, respectively, in 2006 (Marchese). 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.

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Herbicide-Resistant Crops

Herbicide-resistant crops planted in the United States included alfalfa, canola, corn, cotton and soybean. We have reviewed all of these crops except alfalfa, which is the newest crop variety available. For all other crops, the adoption of the herbicide technology was large, and amounted to slight increases over 2005. Alfalfa is in the process of being introduced and will likely be a crop included in next year's report. Registration and other factors are still a problem for growers to contend with on a day-to-day basis.

The rapid advancement of herbicide resistant crops since 1996 is largely due to the enhanced flexibility of weed management that they offer. They are fairly robust in terms of when to apply, pre-emergent or post-emergent. The window for consideration of application is therefore rather wide. This gives growers significant flexibility in terms of scheduling activities during one of the most demanding times of the year.

3. Canola

Again in 2006, North Dakota was the dominant canola producing state, planting approximately 90 percent of the total planted acreage—down from 92 percent in 2005. Other states planted minor acreages of canola and included Idaho, Michigan, Minnesota, Montana, Oklahoma, Oregon, and Washington. Minnesota was the second largest in acreage planted with 2.5 percent of the total (National Agricultural Statistics Service Acreage).

Acreage planted in North Dakota was off about one hundred thousand in 2006 compared to 2005. Still, total planted acreage was about the same as in 2005, 1,044,000 acres as against 1,040,000 acres. Record yields of canola per acre were off as well in 2006, with total production down from 1.462 million pounds to 1.281 million pounds. There does not seem to be much of a reason for this as the price was in fact higher. The reason if any was the competition from other crops. All major crops had significant increases in prices in 2006. Lower production costs and simplified weed management associated with glyphosate-resistant soybean have made the soybean a more appealing crop in Minnesota and to some extent in North Dakota (Jenks 2006).

The adoption of biotechnology-derived herbicide-resistant canola increased again in 2006, from 98 to 99 percent. Essentially all of the canola in both Minnesota and North Dakota is herbicide-resistant. Minnesota had a figure of 78 percent planted to the herbicide-resistant cultivar in 2006. The increased adoption of biotechnology-derived canola in 2005 and 2006 is attributed to herbicide–resistant trait and the related reduction in production costs (Tables 3.2 and Table 2.3).

As in years earlier, farmers planted glyphosate-resistant and glufosinate-resistant varieties, Table 3.2. Imazamox-resistant canola was planted to 8 percent of the acres in the nation as well. Glyphosate-resistant (Roundup Ready) canola varieties were planted to 57 percent of the acres in North Dakota and 50 percent of the acres in Minnesota. Plantings of gyphosate-resistant canola were 37 percent in North Dakota and 25 percent of total acreage on Minnesota. These proportions of acreage continued the trend to increased plantings to glufosinate-resistant (Liberty Link) observed in recent years in North Dakota.

Both glyphosate and glufosinate provided viable weed management options to canola growers related to their broad spectrum of activity, convenient post emergence-based programs and control of special 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, Canadian thistle, wild buckwheat, wild oat and yellow foxtail, as well as seed contaminates such as wild mustard which may cause price discounts 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 are assumed to be similar to North Dakota in Minnesota (Jenks 2007). The typical weed management program in conventional canola (provided as a control against the herbicide-resistant canola) cost about $36.47 in 2006. The weed management costs for glyphosate-resistant and glufosinate-resistant canola were about $25.25 and $27.45, respectively. These costs included the cost of the premium for the biotechnology-derived trait seed which was $5 in both cases. We added another biotechnology-derived variety in 2006, imazamox-resistant canola. This variety had the same seed cost premium as the other two herbicide resistant varieties but a higher cost of the post emergent application.

The impacts of planting herbicide-resistant canola in the two states are provided in Table 3.5. In total, canola growers saved $9.5 million on weed management from use of the herbicide-resistant varieties in 2006. As in previous years, growers were able to reduce the herbicide use in the biotechnology-derived canola. The reason for the lower saving in 2006 than in 2005 was the reduced acreage planted in North Dakota. Active ingredients per acre for the herbicide-resistant varieties were 0.63 pounds per acre for Roundup Ready, 0.69 pounds per acre for Liberty Link and 0.25 pounds per acre for Clearfield in both North Dakota and in Minnesota (Table 3.5).

The accelerated use of biotechnology-derived varieties of canola is justified from two important vantage points, improved economic results per acre and reduced applications of active ingredients per acre. The results show that the farmers are rational, making the switch to biotechnology-derived varieties in rapid order.

Table 3.1. Canola production in the top producing states

Year	Acres planted[1]		Production[2]		Value[3]	
	North Dakota	Minnesota	North Dakota	Minnesota	North Dakota	Minnesota
	000A		Million lb		Million $	
1997	0	—	0	—	—	—
1992	16	—	22	—	—	—
1997	376	110	427	147	—	—
1998	800	210	1,147	290	117	—
1999	855	105	1,085	130	81	—
2000	1,270	140	1,650	185	108	—
2001	1,300	80	1,799	89	158	7
2002	1,300	80	1,403	45	149	5
2003	970	57	1,354	102	143	10
2004	780	35	1,223	48	131	5
2005	1,040	55	1,462	31	137	3
2006	940	28	1,281	36	142	4

[1]Source: National Agricultural Statistics Service, 2005 Acreage, Crop production 2005 and 2006 summary.

[2]Source: National Agricultural Statistics Service, 2005 Crop Production, Crop production 2005 and 2006 summary.
[3]Source: National Agricultural Statistics Service, 2005 Crop Value, Crop production 2005 and 2006 summary.

Table 3.2. Adoption of biotechnology-derived herbicide-resistant (HR) canola in North Dakota[1] and Minnesota[2] in 2006

State	Planted canola acreage	Total HR canola	Glyphosate-resistant[3] canola	Glufosinate-resistant[4] canola	Imazamox resistant[5] canola	HR canola acreage
	000A	Percent adoption				000A
North Dakota	940	99	57	37	5	931
Minnesota	28	78	50	25	3	22
U.S. Total/Average	**1044**	**87**	**53**	**34**	**8**	**952**

[1]Source: Jenks 2007.
[2]Source: Coleman 2007.
[3]Roundup Ready.
[4]Liberty Link.
[5]Clearfield.

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	Imazamox resistant[4] 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
2006	99	57	37	5	931

[1]Source: Jenks 2007.
[2]Roundup Ready
[3]Liberty Link
[4]Clearfield

Table 3.4. Comparison of weed management costs in various canola systems in 2006[1]

Conventional canola[2]

Herbicides	$/lb ai or ae/A	lb ai or ae/A	$[3]/A
Ethalfluralin (PRE) fb[4]	$10.00/lb ai/A	0.94	$9.40
Quizalofop (POST)+	147.73/lb ai/A	0.056	$8.27
Clopyralid (POST)	$120.00/lb ae/A	0.09	$10.80
Total		1.09	$28.47
Application cost (2 applications)			$8.00
Total weed management costs in conventional canola			$36.47

Glyphosate-resistant canola

Seed premium	$5.00
Technology Fee plus 1 pint or 0.46 lb ai glyphosate (Roundup WeatherMax formulation)	$16.25
Application cost (1 application)	$4.00
Total cost	$25.25

Glufosinate-resistant canola

Seed premium	$5.00
Technology Fee	$0.00
0.37 lb ai/A glufosinate ($15.06) + 0.023 lb ai/A quizalofop ($3.39)	$18.45
Application cost (1 application)	$4.00
Total cost	$27.45

Imazamox-resistant canola

Seed premium	$5.00
Technology Fee	$0.00
.8 lb ai/A ethalfluralin ($8.00) (PRE)[4] + .032lb ai/A imazamox (POST) ($16.64)	$24.64
Application cost (1 application)	$4.00
Total cost	$33.64

[1]Sources: Brian Jenks of North Dakota State University for information on weed management programs. and Barry Coleman of Northern Canola Growers Association for seed costs, seed premium costs, and technology fee information. [2]For the purposes of this analysis, a single program is selected, as above, from several suggested alternative programs.
[3]Herbicide costs were calculated form the 2006 North Dakota Herbicide Compendium.
[4]Followed by.

Table 3.5. Impacts of herbicide-resistant canola on U.S. agriculture in 2006[1]

State	Herbicide-resistance trait	Planted acreage	Reduction in weed management costs		Reduction in herbicide use	
		000A	$/A	Million $	lb/A	000 lb
North Dakota	RR[2]	536	11.22	6.01	0.63	335.4
North Dakota	LL[3]	348	9.02	3.14	0.69	238.6
North Dakota	CF[4]	47	2.83	0.13	0.25	11.9
Impacts due to herbicide-resistant canola in North Dakota				**9.28**		**585.9**
		000A	$/A	Million $	lb/A	000 lb
Minnesota	RR[2]	14	11.22	0.16	0.63	8.8
Minnesota	LL[3]	7	9.02	0.06	0.69	4.9
Minnesota	CF[4]	1	2.83	0.00	0.25	0.2
Impacts due to herbicide-resistant canola in Minnesota				**0.22**		**13.8**
				Million $		000 lb
Impacts due to herbicide-resistant canola in the United States				**9.5**		**599.8**

[1]Based on Tables 3.2 and 3.4

[2]Roundup Ready

[3]Liberty Link

[4]Clearfield

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4. Corn

Corn growers in the US planted two biotechnology-derived herbicide-resistant cultivars in 2006, as was the case in 2005, 2004 and 2003. They were glyphosate-resistant (Roundup Ready corn and Roundup Ready corn 2) and glufosinate-resistant (Liberty Link) corn. Together the above two herbicide-resistant varieties were planted on 53 percent of the total acres of corn in 2006, up from 35 percent in 2005. Several states had total planted acreage in the 80 percent and above range: Arkansas, Nebraska, South Dakota, Texas, Utah, and Wyoming. However, total planted acreage was larger in the Corn Belt states due to higher total acreage planted to corn (Table 4.1).

Planted acreage seeded to biotechnology-derived herbicide-resistant varieties increased from 27,929,000 in 2005 to 41,020,000 acres in 2006. Total acreage was down in 2006 compared to 2005 from 81,759,000 to 79,366,000. Reasons for the surge in adoption of herbicide-resistant varieties include increased availability of the trait hybrids suited to various geographic locations and a partial resolution of the trade restrictions on export markets. In general, the European market is becoming more open to genetically modified varieties of corn. In addition, other countries are importing corn that has biotechnology-derived traits.

Between the two biotechnology-derived herbicide-resistant varieties in the market place, glyphosate-resistant corn was the dominant cultivar in 2006 as in 2005. About 46 percent of the planted acres were seeded to glyphosate-resistant corn in 2006, compared to 31 percent in 2005. Adoption of glufosinate-resistant corn was more variable among the states due to limited variety selection, non availability of the trait in better performing varieties, high price differentials between glufosinate and glyphosate, and ineffectiveness of glufosinate in controlling weeds in corn production such as nutsege, pigweed, and certain grasses. Glyphosate had better controlling capacities for difficult weeds that glufosinate.

The survey of crop specialists indicated that the predominant method of weed control was premix at ½ rate followed by a post emergent application of either herbicide-resistant compound. The glyphosate was at a lower cost, but had a $10 premium for the corn seed. The glufosinate had a higher post emergent cost but no seed premium. In total, both were about the same for weed control, $25.43 for glyphosate-resistant and $26.91 for glufosinate-resistant. The conventional weed control system cost $33.48. Thus, there was a significant cost savings for the use of either herbicide-resistant cultivar, $8 to $6 per acre (Table 4.2). The herbicide rate per acre of active ingredients was as well reduced by about 1.3 pounds per acre for both of the herbicide-resistant varieties.

Total impacts of both Roundup Ready and Liberty Link herbicide-resistant varieties are calculated by state in Tables 4.3 and 4.4. Observe that on a nation-wide basis, reductions in herbicide use were for Roundup Ready 39,500,000 pounds of active ingredients. The reduction in weed management costs was $250,375,000, calculated on the basis of $8.05

difference between conventional tillage and Roundup Ready from Table 4.2. For Liberty Link the comparable numbers are 12,794,000 and $65,160,000, respectively. Aggregating both of the herbicide-resistant cultivars, the numbers for the nation are provided in Table 4.5. Clearly they are substantial and resulted in significant increases in farm income in 2006.

The comments on conservation tillage are the same as for 2005. This is because the Conservation Technology Information Center has not produced a survey similar to the one through 2004 since that time. Antidotal information from the crop specialists indicates that the conservation tillage has increased both in 2005 and 2006. The major reason is that the tillage cost is lower with the herbicide-resistant crops. With increases in fuel and other costs per acre, we expect the conservation tillage to increase, pushing up the use of herbicide-resistant varieties of corn.

Table 4.1. Adoption of biotechnology-derived herbicide-resistant (HR) corn in the United States in 2006.

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	230	68	156	6	14	74	170	dmrkynetec/Kuykendall
AZ	55	15	8	2	1	17	9	McCloskey/McCloskey
AR	170	85	145	1	2	86	146	dmrkynetec/Smith
CA	540	45	243	1	5	46	248	dmrkynetec/Lanini
CO	1,000	62	620	10	100	72	720	dmrkynetec/Meyer
DE	165	44	73	2	3	46	76	dmrkynetec/VanGessel
GA	280	69	193	4	11	73	204	dmrkynetec/Prostko
ID	270	57	154	0	0	57	154	dmrkynetec/Morishita
IL	11,600	27	3,132	5	580	32	3,712	dmrkynetec/Hager
IN	5,500	23	1,265	3	165	26	1,430	dmrkynetec/Bauman
IA	12,700	28	3,556	40	5,080	68	8,636	dmrkynetec/Hartzler
KS	3,400	58	1,972	5	170	63	2,142	dmrkynetec/Peterson
KY	1,200	23	276	10	120	33	396	dmrkynetec/Ewing
LA	300	35	105	1	3	36	108	dmrkynetec/Lanclos
MA	19	55	10	10	2	65	12	Barlow/Barlow
MD	480	34	163	1	5	35	168	dmrkynetec/Kratochvil
MI	2,200	34	748	5	110	39	858	dmrkynetec/Sprague
MN	7,300	55	4,015	10	730	65	4,745	dmrkynetec/Gunslous
MS	300	67	201	2	6	69	207	dmrkynetec/[4]
MO	2,750	15	413	5	138	20	550	dmrkynetec/Bradley
NC	740	42	311	4	30	46	340	dmrkynetec/York
ND	1,750	75	1,313	10	175	85	1,488	dmrkynetec/Ransom
NE	8,300	46	3,818	10	830	56	4,648	dmrkynetec/Nelson
NJ	75	50	38	1	1	51	38	Majek/Majek
NM	130	23	30	3	4	26	34	dmrkynetec/Carrillo
NY	970	52	504	1	10	53	514	dmrkynetec/Hahn
OH	3,300	17	561	1	33	18	594	dmrkynetec/Thomison
OK	310	68	211	5	16	73	226	dmrkynetec/Medlin
PA	1,350	15	203	40	540	55	743	dmrkynetec/Curran
SC	300	26	78	10	30	36	108	dmrkynetec/Wiatrak
SD	4,400	79	3,476	5	220	84	3,696	dmrkynetec/Moechnig
TN	600	25	150	20	120	45	270	dmrkynetec/Hayes
TX	1,750	78	1,365	5	88	83	1,453	dmrkynetec/Baumann
UT	65	80	52	2	1	82	53	Whitesides/Whitesides
VA	510	45	230	2	10	47	240	dmrkynetec/Wilson
VT	95	25	24	2	2	27	26	Giguere/Giguere
WV	44	37	16	3	1	40	18	Chandran/Chandran
WI	3,750	32	1,200	15	563	47	1,763	dmrkynetec/Boerboom
WY	90	85	77	1	1	86	77	dmrkynetec/Kniss
Total/Average	**78,988**	**46**	**31,102**	**7**	**9,918**	**53**	**41,020**	
US Total/Average	**79,366**	**46**		**7**		**53**		

[1]Source: National Agricultural Statistics Service, 2006 Acreage. [2]RR = Glyphosate-resistant or Roundup Ready corn.
[3]LL = Glufosinate-resistant or Liberty Link corn. [4]Estimate based on neighboring states.

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

Program	Herbicide rate	Herbicide costs[2]
	lb ai/A	$/A
Conventional corn		
Premix of Metolachlor + Atrazine[3] as PRE	2.89	23.63
(1.63 + 1.26 ai/A, respectively)		
followed by		
Mesotrione[4] + premix of Nicosulfuron + Rimsulfuron[5] as	0.22	9.85
POST (both half rates, .03 + .185 lb ai/A, respectively)		
Total for conventional program	**3.11**	**33.48**
Glyphosate-resistant (Roundup Ready or RR) corn		
Premix of Metolachlor + Atrazine[3] as PRE	1.45	11.82
half rate (.82 + .63 ai/A, respectively)		
followed by		
Glyphosate[6] as POST (1 pass)	0.39	3.61
Seed premium costs/technology fee		10.00
Total for RR program	**1.84**	**25.43**
Glufosinate-resistant (Liberty Link or LL) corn		
Premix of Metolachlor + Atrazine[3] as PRE	1.45	11.82
half rate (.82 + .63 ai/A, respectively)		
followed by		
Glufosinate[7] as POST (1 pass)	0.37	15.09
Seed premium costs/technology fee		0.00
Total for LL program	**1.82**	**26.91**
Difference	**-1.27**	**8.05**
	-1.29	**6.57**

[1]Based on survey of Weed Specialists listed in References section.
[2]Herbicide costs were calculated form the 2006 North Dakota Herbicide Compendium.
[3]Trade name: Bicep II Magnum.
[4]Trade name: Callisto.
[5]Trade name: Steadfast.
[6]Trade name: Roundup WeatherMax.
[7]Trade name: Liberty.

Table 4.3. Impacts of herbicide-resistant Roundup Ready (RR) corn in 2006

State	Total corn acres planted	RR corn acreage	Impacts due to RR corn: Reduction in herbicide use[1]	Impacts due to RR corn: Reduction in weed management costs[2]
	000A	000A	000 lb ai	000$
AL	230	156	199	1,259
AZ	55	8	10	66
AR	170	145	184	1,163
CA	540	243	309	1,956
CO	1,000	620	787	4,991
DE	165	73	92	584
GA	280	193	245	1,555
ID	270	154	195	1,239
IL	11,600	3,132	3,978	25,213
IN	5,500	1,265	1,607	10,183
IA	12,700	3,556	4,516	28,626
KS	3,400	1,972	2,504	15,875
KY	1,200	276	351	2,222
LA	300	105	133	845
MA	19	10	13	84
MD	480	163	207	1,314
MI	2,200	748	950	6,021
MN	7,300	4,015	5,099	32,321
MS	300	201	255	1,618
MO	2,750	413	524	3,321
NC	740	311	395	2,502
ND	1,750	1,313	1,667	10,566
NE	8,300	3,818	4,849	30,735
NF	75	38	48	302
NM	130	30	38	241
NY	970	504	641	4,060
OH	3,300	561	712	4,516
OK	310	211	268	1,697
PA	1,350	203	257	1,630
DX	300	78	99	628
SD	4,400	3,476	4,415	27,982
TN	600	150	191	1,208
TX	1,750	1,365	1,734	10,988
UT	65	52	66	419
VA	510	230	291	1,847
VT	95	24	30	191
WV	44	16	21	131
WI	3,750	1,200	1,524	9,660
WY	90	77	97	616
Total	**78,988**	**31,102**	**39,500**	**250,375**

[1]Calculated at 1.27 lb ai/A based on Table 4.2.

[2]Calculated at $8.05/A based on Table 4.2.

Table 4.4. Impacts of herbicide-resistant Liberty Link (LL) corn in 2006

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	230	14	18	91
AZ	55	1	1	7
AR	170	2	2	11
CA	540	5	7	35
CO	1,000	100	129	657
DE	165	3	4	22
GA	280	11	14	74
ID	270	0	0	0
IL	11,600	580	748	3,811
IN	5,500	165	213	1,084
IA	12,700	5,080	6,553	33,376
KS	3,400	170	219	1,117
KY	1,200	120	155	788
LA	300	3	4	20
MA	19	2	2	12
MD	480	5	6	32
MI	2,200	110	142	723
MN	7,300	730	942	4,796
MS	300	6	8	39
MO	2,750	138	177	903
NC	740	30	38	194
ND	1,750	175	226	1,150
NE	8,300	830	1,071	5,453
NF	75	1	1	5
NM	130	4	5	26
NY	970	10	13	64
OH	3,300	33	43	217
OK	310	16	20	102
PA	1,350	540	697	3,548
DX	300	30	39	197
SD	4,400	220	284	1,445
TN	600	120	155	788
TX	1,750	88	113	575
UT	65	1	2	9
VA	510	10	13	67
VT	95	2	2	12
WV	44	1	2	9
WI	3,750	563	726	3,696
WY	90	1	1	6
Total	**78,988**	**9,918**	**12,794**	**65,160**

[1]Calculated at 1.29 lb ai/A based on Table 4.2.
[2]Calculated at $6.57/A based on Table 4.2.

Table 4.5. Aggregate impacts of herbicide-resistant (HR) corn in 2006[1]

State	Total corn acres planted	HR corn acreage	Impacts due to HR corn	
			Reduction in herbicide use[1]	Reduction in weed management costs[2]
	000A	000A	000 lb ai	000$
AL	230	170	246	1,309
AZ	55	9	14	72
AR	170	146	211	1,125
CA	540	248	359	1,911
CO	1,000	720	1,041	5,538
DE	165	76	110	584
GA	280	204	295	1,572
ID	270	154	222	1,184
IL	11,600	3,712	5,366	28,553
IN	5,500	1,430	2,067	11,000
IA	12,700	8,636	12,483	66,430
KS	3,400	2,142	3,096	16,477
KY	1,200	396	572	3,046
LA	300	108	156	831
MA	19	12	18	95
MD	480	168	243	1,292
MI	2,200	858	1,240	6,600
MN	7,300	4,745	6,859	36,499
MS	300	207	299	1,592
MO	2,750	550	795	4,231
NC	740	340	492	2,618
ND	1,750	1,488	2,150	11,442
NE	8,300	4,648	6,719	35,753
NF	75	38	55	294
NM	130	34	49	260
NY	970	514	743	3,955
OH	3,300	594	859	4,569
OK	310	226	327	1,741
PA	1,350	743	1,073	5,711
DX	300	108	156	831
SD	4,400	3,696	5,343	28,430
TN	600	270	390	2,077
TX	1,750	1,453	2,100	11,173
UT	65	53	77	410
VA	510	240	346	1,844
VT	95	26	37	197
WV	44	18	25	135
WI	3,750	1,763	2,548	13,557
WY	90	77	112	595
Total	**78,988**	**41,020**	**59,294**	**315,535**

[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-til 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	19.1	14
2004	15.82	19.7	20

Source: Conservation Technology Information Center.

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5. Cotton

US farmers planted 15,274,000 acres of cotton in 2006, up from the 13,925,000 acres in 2005. The adoption rate for biotechnology-derived herbicide-resistant cotton seed was 86.4 percent, with glyphosate-resistant at 82.9 percent and glufosinate at 3.5 percent. Most states had adoption rates in the 90+ percentage rate, with the exceptions being Arizona and California and Texas. These states have fewer weed management problems than the others, mainly Southern states.

The two biotechnology-derived herbicide-resistant cotton cultivars that were planted in 2006 are glyphodsate-resistant (Roundup Ready) and glufosinate-resistant (Liberty Link). Production of bromoxynil-resistant cotton, an herbicide-resistant variety planted since 1995, ceased in 2005, due to effectiveness on certain weeds and restrictions placed in bromoxynil by the USEPA.

Both glyphosate-resistant and glufosinate are post emergence, non-residual, non selective herbicides; however, there are contrasts in their use for weed management programs. Where as glyphosate can be applied over the top (broadcast) only up to the 4-5 leaf stage of first plant generation, glufosinate has a larger over the top application window and can be applied up to 70 days to harvest (Lemon 2004). Thus the timing of herbicide application is more flexible with the glufosinate-resistant cotton (Culpeper 2007).

Unlike glyphosate, glufosinate is not effective against nutsedge, grasses and pigweed. Control of morning glory, smartweed and hemp sesbana on the other hand is superior with glufosinate compared to glyphosate. Another difference between the two systems is that glyphosate is used as needed applications until lay-by while glufosinate is used in more of a pre-planned, traditional program of weed control. In 2006, this has changed due to the introduction of Roundup Ready Flex cotton, which posses both vegetative and reproductive tolerance to glyphosate and can be applied over the top for cotton from the emergence through seven days prior to harvest without concern for crop injury (Murdock 2006).

Typical weed management programs in various cotton growing states are provided in Table 5.2. In some states virtually no non herbicide-resistant cotton is grown. In these states the non herbicide-resistant weed management programs were estimated by applying 2006 prices to the 2005 amounts of compounds. For the states that have virtually no non herbicide-resistant cotton, the crop specialists indicated that the conventional weed control costs will get further and further out of date. With these qualifications, the costs of conventional weed control strategies are reported in Table 5.2 and show an average cost for weed control of $46.20 and pounds of the compounds used were 4.75.

Tables 5.3a and 5.4a show the weed management programs for the glyphosate-resistant (Roundup Ready) resistant cotton. These program costs average $31.66 and have pounds of active ingredients applied per acre of 2.9. National impacts of the Roundup Ready cotton weed management costs are provided in Table 5.4a. The results of these calculations are: impacts for herbicide use reduced 1.81 per acre; costs of weed management program reduced $14.54 per acre or in totals use of active ingredients for all states was a reduction of 23,718,000; and costs of weed control for all states reduced by $228,934,000.

Similar figures are shown for glufosinate-resistant cotton (Liberty Link) in Table 5.4b. Recall that the acreage planted to this herbicide-resistant cotton was considerably smaller than that for the Roundup Ready cotton. Still the differences are significant. On a per acre basis, the average reduction in active ingredients is 1.8 pounds and the reduction in cost per acre is $15.39. Total reductions in pounds of active ingredients are estimated at 728,000 and total reductions in cost are estimated at $1,199,000.

Overall impacts of the two herbicide-resistant cotton varieties are summed in Table 5.5. Reductions in active ingredients are estimated at 24,446,000 pounds and reductions in costs are estimated at $230,133,000. These are rather large given the national net farm income figures for 2006.

Impacts of herbicide-resistant cotton on other weed management costs in 2006 are provided in Table 5.6. The adoption costs are provided in Table 5.7. These include costs of seed premiums and technology. The assumptions are given in the notes to the Table 5.7. Note that these were highly variable as reported by the crop specialists. Thus they should be treated as indicators of the total adoption costs. For both herbicide-resistant cotton varieties the total adoption costs were estimated at $375,663,000. Taking these numbers and making a summation provides the figures presented in Table 5.8. Adoption costs include herbicide costs and application costs, and add to $375,663,000. Tillage costs are reduced by $74,551,000, hand weeding by $60,355,000 and the total is reduced by $27,696,000.

All of these numbers for cotton are likely to change significantly in the next few years as Roundup Ready Flex and with Bollgard stacked trait insect protected cotton promises to bring added savings to cotton growers. The Roundup Ready Flex will make it possible to treat cotton with herbicides almost until harvest. The flexibility and the increased weed control will almost certainly increase the value of the herbicide-resistant brands of cotton. We look to a day when the insects and weed pests can be controlled by a single set of cotton varieties.

Table 5.1. Herbicide-resistant (HR) cotton adoption in the United States in 2006[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	000 Acres	000A
AL	575	97.02	0	97.02	558	0	558
AZ	197	75.28	1.25	76.53	148	2	151
AR	1,170	98.32	1.25	99.57	1,150	15	1,165
CA	560	56.66	0.40	57.06	317	2	320
FL	103	97.51	0	97.51	100	0	100
GA	1,400	98.00	0.20	98.2	1,372	3	1,375
KS	115	97.78	0	97.78	112	0	112
LA	635	98.52	0.76	99.28	626	5	630
MS	1,230	98.24	1.04	99.28	1,208	13	1,221
MO	500	99.70	0	99.70	499	0	499
NM	63	82.81	0	82.81	52	0	52
NC	870	99.43	0.3	99.73	865	3	868
OK	320	98.20	0	98.20	314	0	314
SC	300	100.00	0	100.00	300	0	300
TN	700	99.03	0	99.03	693	0	693
TX	6,431	65.94	7.69	73.63	4,241	495	4,735
VA	105	96.09	0.67	96.76	101	1	102
Total/ Average	**15,274**	**82.9**	**3.5**	**86.4**	**12,657**	**538**	**13,195**

[1]Source: Agricultural Marketing Service. Cotton Varieties Planted, United States, 2006 Crop.
[2]Source: National Agricultural Statistics Service. 2006 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 U.S. in 2006 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	47.93
AZ	Pendimethalin (1.5)		Pyrithiobac (0.063) + MSMA (2.0)		Prometryn (0.5)	4.1	42.93
AR[4]	Pendimethalin (0.6)	Fluometuron (0.5)	Pyrithiobac (0.063)	MSMA (2.0)	Prometryn (1.0)	4.2	46.43
CA	Trifluralin (1.0)		Pyrithiobac (0.063)	Carfentrazone (0.13)	Prometryn (0.5) + MSMA (2.0)	3.7	40.58
FL	Pendimethalin	Fluometuron (1.5)	Prometryn (0.75) + MSMA (2.0)			5.0	32.38
GA	Pendimethalin (0.75)	Fluometuron (1.0)	Pyrithiobac (0.063) + MSMA (0.75)		Diuron (1.0) + MSMA (2.0)	5.6	50.54
KS	Pendimethalin (1.0)	Fluometuron (1.0)	Clethodim (0.125)	Prometryn (.75)	Diuron (1.0) + MSMA (2.0)	5.9	59.80
LA[4]		Pendimethalin (0.75) + Fluometuron (0.75)	Pyrithiobac (0.063)	Fluometuron (0.75) + MSMA (2.0)	Diuron (1.0)	5.3	53.43
MS[4]	Pendimethalin (1.0)		Pyrithiobac (0.063)	Prometryn (0.5) fb[5] MSMA (2.0)	Diuron (1.0) + MSMA (1.5)	6.1	48.82
MO[4]		Fluometuron (1.2)	Clethodim (0.09)	Fluometuron (1.0) + MSMA (1.5)	Diuron (1.0) + MSMA (1.5)	6.3	53.98
NM	Trifluralin (0.5)	Fluometuron (1.0)		Diuron (1.0) + MSMA (2.0)		4.5	23.76
NC[4]	Pendimethalin (0.75)	Fluometuron (1.0)	Pyrithiobac (0.07)	Prometryn (.75)	MSMA (2.0) + Prometryn (0.5)	5.1	57.21
OK	Pendimethalin (0.63)			Fluometuron (1.0) fb[5] Prometryn (0.8)	Diuron (0.75)	3.2	25.15
SC[4]	Pendimethalin (0.83)	Fluometuron (1.0)	Pyrithiobac (0.063)	Prometryn (1.0) + MSMA (2.0)		4.9	52.97
TN[4]	Trifluralin (0.75)	Fluometuron (1.4)	Pyrithiobac (0.06) + Clethodim (0.125)	Diuron (1.0) + MSMA (2.0)		5.3	76.78
TX	Trifluralin (1.0)		Pyrithiobac (0.063) + MSMA (0.75)	Prometryn (1.5) + MSMA (1.0)		4.3	47.48
VA	Pendimethalin (0.63)	Fluometuron (1.0)		Prometryn (0.8)	Diuron (0.75)	3.2	25.15
Average						**4.75**	**46.20**

[1]Specialists that specified the weed mgt. programs for their respective state are listed in the References.
[2]PPI = preplant incorporated; PRE = preemergence; POST = postemergence; POST-DRI = post-directed.
[3]Weed management program costs were calculated based on Ferrell and McDonald's University of Florida's Approximate Herbicide Pricing – 2006.
[4]Virtually no conventional cotton is grown in these states. Herbicide program costs are based on 2005's herbicide program using 2006 pricing.
[5]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 two postemergence applications of glyphosate[2], followed by prometryn as layby treatment.	0.75 + 0.75 + 0.75 + 0.5	2.75	24.19
2. Three postemergence applications of glyphosate.	1.0 + 1.0 + 1.0	3.0	30.00
3. Pendimethalin preemergence, followed by glyphosate at four leaf stage, followed by diuron + MSMA as layby treatment.	0.75 + 1.0 + 1.0 + 2.0	4.75	25.63
4.Glyphosate + pyrithiobac preemergence, followed by two post emergence applications of glyphosate.	0.75 + 0.048 + 1.0 + 0.5	2.3	39.87
5. Pendimethalin preemergence followed by postemergence applications of glyphosate + pyrithiobac followed by glyphosate + prometryn as post-dir treatment.	0.75 + 0.75 + 0.048 + 0.5 + 0.5	2.55	39.37
6.Two postemergence applications of glyphosate followed by prometryn as post-dir treatment.	1.0 + .05 + 0.5	2.0	24.50
7. Pendimethalin preemergence followed by one postemergence application of glyphosate + metolachor followed by glyphosate + diuron as post-dir.	0.75 + 0.75 + 0.95 + 0.75 + 0.75	3.2	38.05
Average		**2.94**	**31.66**

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

[2]Roundup WeatherMax formulation was 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 two postemergence applications of glufosinate (early to mid post and late post) followed by diuron + MSMA as layby treatment.	0.75 + 0.42 + 0.42 + 0.75 + 2.0	4.34	54.62
2. Pendimethalin premergence followed by one postemergence application of glufosiante (mid to late post) followed by diuron + MSMA as layby treatment.	0.75 + 0.42 + 0.75 + 2.0	3.92	34.50
3. Two postemergence applications of glufosinate (at two leaf stage followed by 5 to 6 leaf stage) followed by diuron + MSMA as layby treatment.	0.42 + 0.42 + 0.75 + 2.0	3.59	49.62
4. Glufosinate at two leaf stage followed by glufosinate + metolachlor at 5 to 6 leaf stage followed by diuron + MSMA as layby treatment.	0.42 + 0.21 + 0.95 + 0.75 + 2.0	4.33	53.86
5. Pendimethalin premergence followed by two postemergence applications of glufosinate (early to mid post and late post to layby).	0.75 + 0.42 + 0.42	1.59	45.24
6. Three glufosinate applications (early post, mid post, layby).	0.42 + 0.42 + 0.21	1.05	50.30
7. Pendimethalin + diuron premergence followed by one postemergence application of glufosinate.	1.0 + 0.75 + 0.42	2.17	28.87
Average		**3.00**	**45.29**

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

So very little glufosinate-resistant cotton is planted that it was hard to pin the weed specialists down on a treatment program. We used the programs from last year and updated the "cost" column. The weed specialist in Alabama did say that he thought glufosinate-resistant cotton might be planted more as more weeds become resistant to glyphosate.

Table 5.4a. Impacts of glyphosate-resistant (Roundup Ready/RR) cotton on herbicide use and weed management costs in 2006

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	575	558	4.1	47.93	-1.16	-16.27	-647	-9,076
AZ	197	148	4.1	42.93	-1.16	-11.27	-172	-1,671
AR	1,170	1,150	4.2	46.43	-1.26	-14.77	-1,449	-16,991
CA	560	317	3.7	40.58	-0.76	-8.92	-241	-2,830
FL	103	100	5.0	32.38	-2.06	-0.72	-207	-72
GA	1,400	1,372	5.6	50.54	-2.66	-18.88	-3,650	-25,903
KS	115	112	5.9	59.80	-2.96	-28.14	-333	-3,164
LA	635	626	5.3	53.43	-2.36	-21.77	-1,476	-13,619
MS	1,230	1,208	6.1	48.82	-3.16	-17.16	-3,818	-20,735
MO	500	499	6.3	53.98	-3.36	-22.32	-1,675	-11,127
NM	63	52	4.5	23.76	-1.56	7.90	-81	412
NC	870	865	5.1	57.21	-2.16	-25.55	-1,868	-22,102
OK	320	314	3.2	25.15	-0.26	6.51	-82	2,046
SC	300	300	4.9	52.97	-1.96	-21.31	-588	-6,393
TN	700	693	5.3	76.78	-2.36	-45.12	-1,636	-31,278
TX	6,431	4,241	4.3	47.48	-1.36	-15.82	-5,767	-67,086
VA	105	101	3.2	25.15	-0.26	6.51	-26	657
U.S.	**15,274**	**12,657**	**4.75**	**46.20**	**-1.81**	**-14.54**	**-23,718**	**-228,934**

[1]Average herbicide use in RR cotton in 2006 = 2.94 lb ai/A (from Table 5.3a).
[2]Average cost of weed management program in RR cotton in 2006 = $31.66 (from Table 5.3a).

Table 5.4b. Impacts of glufosinate-resistant (Liberty Link/LL) cotton on herbicide use and weed management costs in 2006

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	575	0	4.1	47.93	-1.1	-2.64	0.0	0.0
AZ	197	2	4.1	42.93	-1.1	2.36	-2.7	5.8
AR	1,170	15	4.2	46.43	-1.2	-1.14	-17.6	-16.7
CA	560	2	3.7	40.58	-0.7	4.71	-1.6	10.6
FL	103	0	5	32.38	-2	12.91	0.0	0.0
GA	1,400	3	5.6	50.54	-2.6	-5.25	-7.3	-14.7
KS	115	0	5.9	59.8	-2.9	-14.51	0.0	0.0
LA	635	5	5.3	53.43	-2.3	-8.14	-11.1	-39.3
MS	1,230	13	6.1	48.82	-3.1	-3.53	-39.7	-45.2
MO	500	0	6.3	53.98	-3.3	-8.69	0.0	0.0
NM	63	0	4.5	23.76	-1.5	21.53	0.0	0.0
NC	870	3	5.1	57.21	-2.1	-11.92	-5.5	-31.1
OK	320	0	3.2	25.15	-0.2	20.14	0.0	0.0
SC	300	0	4.9	52.97	-1.9	-7.68	0.0	0.0
TN	700	0	5.3	76.78	-2.3	-31.49	0.0	0.0
TX	6,431	495	4.3	47.48	-1.3	-2.19	-642.9	-1,083.1
VA	105	1	3.2	25.15	-0.2	20.14	-0.1	14.2
U.S.	**15,274**	**538**	**4.75**	**46.20**	**-1.8**	**-15.39**	**-728**	**-1199**

[1]Average herbicide use in LL cotton in 2006 = 3.00 lb ai/A (from Table 5.3b).
[2]Average cost of weed management program in LL cotton in 2006 = $45.29 (from Table 5.3b).

Table 5.5. Overall impact[1] of herbicide-resistant cotton on herbicide use and weed management costs in 2006

State	Total planted cotton acreage	Total HR cotton acreage	Impacts on	
	000A	000A	**Herbicide use 000 lb**	**Weed management costs 000$**
AL	575	558	-647	-9,076
AZ	197	151	-175	-1,666
AR	1,170	1,165	-1,467	-17,007
CA	560	320	-243	-2,820
FL	103	100	-207	-72
GA	1,400	1,375	-3,657	-25,918
KS	115	112	-333	-3,164
LA	635	630	-1,488	-13,659
MS	1,230	1,221	-3,858	-20,780
MO	500	499	-1,675	-11,127
NM	63	52	-81	412
NC	870	868	-1,874	-22,133
OK	320	314	-82	2,046
SC	300	300	-588	-6,393
TN	700	693	-1,636	-31,278
TX	6,431	4,735	-6,410	-68,169
VA	105	102	-26	671
U.S.	**15,274**	**13,195**	**-24,446**	**-230,133**

[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 2006

State	HR cotton adoption		Tillage		Herbicide application		Hand weeding		
	%	000A	#/A[1]	000$[2]	Trips/A[3]	000$[4]	000A[5]	Hours/A[6]	000$[7]
AL	97.02	558	-2.0	-5,021	0	0	39	-1.0	-385
AZ	76.53	151	-2.5	-1,696	-1	-603	46	-4.0	-1,816
AR	99.57	1,165	-1.0	-5,242	-2	-9,320	420	-2.0	-8,291
CA	57.06	320	-2.5	-3,595	-1	-1,278	323	-8.0	-25,504
FL	97.51	100	-2.0	-904	0	0	0	0	0
GA	98.2	1,375	-1.0	-6,187	-1	-5,499	61	-2.5	-1,505
KS	97.78	112	-1.0	-506	-2	-900	3	-2.0	-59
LA	99.28	630	-1.0	-2,837	-1	-2,522	77	-2.5	-1,900
MS	99.28	1,221	-1.0	-5,495	-1	-4,885	121	-2.5	-2,986
MO	99.7	499	-1.0	-2,243	-1	-1,994	88	-2.5	-2,171
NM	82.81	52	-3.0	-704	0	0	0	0	0
NC	99.73	868	-2.5	-9,761	-2	-6,941	8	-1.0	-79
OK	98.2	314	-1.0	-1,414	0	0	12	-6.0	-711
SC	100	300	-2.5	-3,375	-1	-1,200	27	-1.0	-266
TN	99.03	693	-1.0	-3,119	-1	-2,773	64	-2.5	-1,579
TX	73.63	4,735	-1.0	-21,308	0	0	885	-1.5	-13,102
VA	96.76	102	-2.5	-1,143	-1	-406	0	0	0
U.S.	**92.48**	**13,195**	**-1.7**	**-74,551**	**-0.9**	**-38,320**	**2,174**	**-2.3**	**-60,355**

[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, 2005.
[3] As suggested by cotton weed specialists.
[4] Calculated at $4.00/A for each application, 2005.
[7] Calculated at $9.87 (based on farm labor wage rates reported by NASS for 2006) of hand weeding times the number of acres on which hand weeding is estimated reduced.

Table 5.7. Adoption costs[1] of herbicide-resistant (HR) cotton in 2006

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	558	558	16,178	0	0	16,178
AZ	151	148	4,301	2	39	4,340
AR	1,165	1,150	33,360	15	234	33,594
CA	320	317	9,202	2	36	9,237
FL	100	100	2,913	0	0	2,913
GA	1,375	1,372	39,788	3	45	39,833
KS	112	112	3,261	0	0	3,261
LA	630	626	18,142	5	77	18,220
MS	1,221	1,208	35,042	13	205	35,247
MO	499	499	14,457	0	0	14,457
NM	52	52	1,513	0	0	1,513
NC	868	865	25,086	3	42	25,128
OK	314	314	9,113	0	0	9,113
SC	300	300	8,700	0	0	8,700
TN	693	693	20,103	0	0	20,103
TX	4,735	4,241	122,977	495	7,913	130,890
VA	102	101	2,926	1	11	2,937
U.S.	**13,195**	**12,657**	**367,062**	**538**	**8,602**	**375,663**

[1]Assumptions on adoption costs for 2006 are based on surveys of Extension Specialists. Technology for glyphosate-resistant cotton + $29.00/acre; seed premium/technology fee costs for Liberty Link cotton = $16.00/acre.

Table 5.8. Summary of weed management cost changes in cotton due to biotechnology-derived herbicide-resistant varieties in 2006[1]

State	Herbicide costs	Application costs	Adoption costs	Tillage costs	Hand weeding costs	Total
	000$/year					
AL	-9,076	0	16,178	-5,021	-385	1,696
AZ	-1,666	-603	4,340	-1,696	-1,816	-1,441
AR	-17,007	-9,320	33,594	-5,242	-8,291	-6,266
CA	-2,820	-1,278	9,237	-3,595	-25,504	-23,959
FL	-72	0	2,913	-904	0	1,936
GA	-25,918	-5,499	39,833	-6,187	-1,505	724
KS	-3,164	-900	3,261	-506	-59	-1,368
LA	-13,659	-2,522	18,220	-2,837	-1,900	-2,698
MS	-20,780	-4,885	35,247	-5,495	-2,986	1,101
MO	-11,127	-1,994	14,457	-2,243	-2,171	-3,079
NM	412	0	1,513	-704	0	1,221
NC	-22,133	-6,941	25,128	-9,761	-79	-13,786
OK	2,046	0	9,113	-1,414	-711	9,034
SC	-6,393	-1,200	8,700	-3,375	-266	-2,534
TN	-31,278	-2,773	20,103	-3,119	-1,579	-18,646
TX	-68,169	0	130,890	-21,308	-13,102	28,310
VA	671	-406	2,937	-1,143	0	2,059
U.S.	**-230,133**	**-38,320**	**375,663**	**-74,551**	**-60,355**	**-27,696**

[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	0.067	4.9	31
2000	1.35	8	166
2002	2.03	14	300
2004	2.4	18	371

Source: Conservation Technology Information Center.

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6. Soybean

In 2006, about 90 percent of the soybean acreage was planted to biotechnology-derived herbicide-resistant varieties (Table 6.1). Overall, 2005 acreage increased from 73,303,000 acres to 75,522,000 acres in 2006 for an increase of approximately 2+ million acres. The price of soybeans was the major reason for the increase in acres planted. The adoption of herbicide-resistant varieties was distributed evenly across states. The lowest states in adoption were Kansas, Missouri, Pennsylvania, Texas, and Wisconsin at 85 percent.

The simplicity, flexibility, safety, and economics of weed management programs based on the glyphosate-resistant varieties have had a significant influence on the adoption in the US. Using glyphosate as the primary herbicide for soybean weed control, farmers have realized greater flexibility in timing of herbicide applications, simplicity in herbicide mixes and rates of application, effective control of perennial and hard to control weeds, and economic weed control. These are the main reasons that the adoption of glyphosate-resistant soybean has out-paced the adoption of other herbicide-resistant varieties in other crops.

Herbicides used for weed management in soybean production along with their costs are provided in Table 6.2. The survey of crop specialists surfaced a number of weed management programs used for conventional soybean production. The most typical of these programs, which were argued to provide equivalent control to the glyphosate-resistant technology, are suggested in Table 6.3. A majority of these weed control programs featured pre emergence application (using one or two herbicides) followed by a post emergence application (with one or two herbicides). The herbicide application for glyphosate-resistant soybean was comprised of one timely application of glyphosate alone at about 0.95 pounds of active ingredients per acre (Table 6.4). In some states there were two applications of glyphosate at about 0.72 pounds per acre each.

Costs of the Roundup Ready weed control program are compared to the costs of conventional soybean weed control programs in Table 6.4. The costs of the glyphosate-resistant treatments were $17.20 and $20.92 depending on the number of applications. Active ingredients were again dependent on the number of applications (one or two) and 0.95 or 1.44. The cost of conventional soybean weed control programs range from $25 to $50 depending on the location in the US and weed pressure. Active ingredients ranged from about 2.4 to 0.5 pounds per acre.

Production costs for glyphosate-resistant soybean are provided in Table 6.5. As is shown, the average cost per acre for weed control is $18.17. Reductions in herbicide application are calculated in Table 6.6. Note that the average reduction in application is 0.61, reflecting that for most states the application rate for glyphosate-resistant soybean varieties is one. Application cost savings are estimated at $143,622,000. Aggregate impacts of glyphosate-resistant soybean in 2006 are provided in Table 6.7. Production costs are reduced by approximately $1.5 billion and active ingredients are reduced by 0.50, although this average is of a set of numbers for the different states that is highly variable.

The final information is about no-till acreage and shows that it increased rapidly until 2004, the last year for which figures are available. Antidotal evidence given by the crop specialists indicated that this trend in no till acres in continuing to increase. This could be due to the biotechnology-derived soybean varieties and the treatment possibilities with Roundup. As well, in most areas the cost of limited tillage cultivation methods is lower although the limited tillage cultivation requires more careful management.

Table 6.1. Adoption of glyphosate-resistant (RR) soybean in the United States in 2006

State	Area planted[1]	RR soybean adoption	RR soybean acres	Source[2,3]
	000A	%	000A	
AL	160	95	152	Delaney
AR	3,110	92	2,861	ERS
DE	180	90	162	VanGessel
FL	7	95	7	Brecke
GA	155	90	140	Prostko
IL	10,100	87	8,787	ERS
IN	5,700	92	5,244	ERS
IA	10,150	91	9,237	ERS
KS	3,150	85	2,678	ERS
KY	1,380	60	828	Ewing
LA	870	99	861	Griffin
MD	470	90	423	Ritter
MI	2,000	85	1,700	Sprague
MN	7,350	88	6,468	ERS
MS	1,670	96	1,603	Shaw
MO	5,150	93	4,790	Bradlye
NE	5,050	90	4,545	Nelson
NJ	88	90	79	Majek
NY	200	95	190	Hahn
NC	1,370	90	1,233	Dunphy
ND	3,900	90	3,510	ERS
OH	4,650	90	4,185	Beuerlein
OK	310	95	295	Medlin
PA	430	85	366	Curran
SC	400	90	360	Wiatrak
SD	3,950	98	3,871	Moechnig
TN	1,160	96	1,114	Hayes
TX	225	85	191	Miller
VA	520	85	442	Wilson
WV	17	98	17	Chandran
WI	1,650	85	1,403	ERS
Total/Average	**75,522**	**90**	**67,739**	

[1]Source: National Agricultural Statistics Service, 2006 Acreage.
[2]Affiliations for the Crop Specialists providing soybean adoption information are listed in the References.
[3]USDA Economic Research Service, www.ers.usda.gov.

Table 6.2. Use rates and costs for soybean herbicides in 2006.

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	1.22	14.65
Canopy[2]	Chlorimuron + Metribuzin	4 oz	0.19	13.30
Classic[2]	Chlorimuron + Metribuzin	0.67 oz	0.01	7.37
Dual II Magnum	s-Metolachlor	1.67 pt	1.59	21.90
FirstRate	Cloransulam methyl	0.3 oz	0.016	7.95
Flexstar	Fomesafen	1 pt	0.24	12.50
Frontrow[3]	Cloransulam + Flumetsulan	0.42 oz	0.022	9.33
Fusion	Fluazifor + Fenoxaprop	10 oz	0.21	11.70
Gangster	Flumioxazin + Cloransulam methyl	2.4 oz	0.08	14.55
Harmony Extra	Thifensulfuron	0.6 oz	0.028	7.80
Poast	Sethoxydim	1 pt	0.19	8.15
Prowl	Pendimethalin	3.64 pt	1.5	8.25
Prowl H2O	Pendimethalin	1.5 pt	0.71	6.00
Pursuit	Imazethapyr	1.44 oz	0.063	5.74
Pursuit Plus	Imazethapyr + Pendimethalin	2.5 pt	0.94	15.65
Python	Flumetsulam	1 oz	0.053	9.40
Raptor	Imazamox	5 oz	0.039	20.00
Reflex	Fomesafen	1.5 pt	0.375	18.75
Select	Clethodim	8 oz	0.125	11.60
Sencor	Metribuzin + s-Metolachlor	0.5 lb	0.38	8.00
Storm[2]	Acifluorfen + Bentazon	1.5	0.75	14.06
Squadron[3]	Imazaquin + Pendimethalin	3.0 pt	0.88	13.84
Treflan	Trifluralin	2.0 pt	1.0	6.50
Ultra Blazer	Acifluorfen	1.5 pt	0.375	12.60
Roundup WeatherMax	Glyphosate	22 oz	0.95	7.20

[1]Herbicide costs were calculated based on the "2006 North Dakota Herbicide Compendium" compiled by North Dakota State University.
[2]Herbicide costs were calculated from "Approximate Herbicide Pricing - 2006" compiled by the University of Florida.
[3]Herbicide costs were calculated based on 2004 prices.

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

State	Conventional Program	Source[2]
AL	Squadron fb[3] Storm + Select	Delaney
AR	Squadron fb Storm + Select	Talbert
DE	Canopy + Dual II Magnum (1.25 pt) fb Reflex (1 pt) + Poast	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 (1.25 pt) fb Reflex (1 pt) + Poast	VanGessel
NY	Dual II Magnum + Python + Sencor	Hahn
NC	Squadron fb Storm + Select	York
ND	Flexstar + Raptor	Zollinger
OH	Gangster fb Flexstar + Select	Loutz
OK	Dual II Magnum fb Reflex	Medlin
PA	Dual II Magnum + Python fb Reflex (at half rate)	Curran
SC	Prowl H2O + 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 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 2006[1]

State	Glyphosate-resistant soybean		Conventional soybean	
	$/A	lb ai/A	$/A	lb ai/A
AL	17.20	0.95	39.50	1.76
AR	17.20	0.95	39.50	1.76
DE	17.20	0.95	50.34	1.82
FL	20.92	1.44	23.62	1.89
GA	17.20	0.95	21.87	1.39
IL	17.20	0.95	38.85	1.67
IN	17.20	0.95	41.70	2.40
IA[2]	28.76	0.91	43.65	0.69
KS	17.20	0.95	34.20	1.36
KY	17.20	0.95	24.10	0.37
LA	17.20	0.95	39.50	1.76
MD	17.20	0.95	31.30	1.64
MI	17.20	0.95	38.85	1.67
MN	17.20	0.95	45.10	1.81
MS	20.92	1.44	42.83	1.82
MO	20.92	1.44	38.85	1.67
NE	17.20	0.95	28.25	1.32
NJ	17.20	0.95	50.34	1.82
NY	17.20	0.95	39.30	2.02
NC	17.20	0.95	39.50	1.76
ND	17.20	0.95	32.50	0.28
OH	20.92	1.44	38.65	0.45
OK	17.20	0.95	40.65	1.97
PA	17.20	0.95	40.68	1.83
SC	17.20	0.95	29.47	0.84
SD	17.20	0.95	34.20	1.36
TN	20.92	1.44	37.94	1.25
TX	17.20	0.95	32.45	2.00
VA	17.20	0.95	27.81	2.39
WV	17.20	0.95	24.94	2.36
WI	17.20	0.95	32.60	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 = $7.20/0.95 lb ai. Herbicide applications in glyphosate-tolerant soybean comprised of one timely application of glyphosate at 0.95 lb ai/A or two 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 2006

State	RR soybean acreage	Herbicide use		Royalty fee costs[1]	Herbicide costs[2]	Total cost	Cost/A
	000A	lb ai/A	000 lb/yr	000$	000$	000$	$/A
AL	152	0.95	144	1,520	1,094	2,614	17.20
AR	2,861	0.95	2,718	28,612	20,601	49,213	17.20
DE	162	0.95	154	1,620	1,166	2,786	17.20
FL	7	1.44	10	67	73	139	20.92
GA	140	0.95	133	1,395	1,004	2,399	17.20
IL	8,787	0.95	8,348	87,870	63,266	151,136	17.20
IN	5,244	0.95	4,982	52,440	37,757	90,197	17.20
IA	9,237	0.91	8,405	92,365	173,277	265,642	28.76
KS	2,678	0.95	2,544	26,775	19,278	46,053	17.20
KY	828	0.95	787	8,280	5,962	14,242	17.20
LA	861	0.95	818	8,613	6,201	14,814	17.20
MD	423	0.95	402	4,230	3,046	7,276	17.20
MI	1,700	0.95	1,615	17,000	12,240	29,240	17.20
MN	6,468	0.95	6,145	64,680	46,570	111,250	17.20
MS	1,603	1.44	2,309	16,032	17,507	33,539	20.92
MO	4,790	1.44	6,897	47,895	52,301	100,196	20.92
NE	4,545	0.95	4,318	45,450	32,724	78,174	17.20
NJ	79	0.95	75	792	570	1,362	17.20
NY	190	0.95	181	1,900	1,368	3,268	17.20
NC	1,233	0.95	1,171	12,330	8,878	21,208	17.20
ND	3,510	0.95	3,335	35,100	25,272	60,372	17.20
OH	4,185	1.44	6,026	41,850	45,700	87,550	20.92
OK	295	0.95	280	2,945	2,120	5,065	17.20
PA	366	0.95	347	3,655	2,632	6,287	17.20
SC	360	0.95	342	3,600	2,592	6,192	17.20
SD	3,871	0.95	3,677	38,710	27,871	66,581	17.20
TN	1,114	1.44	1,604	11,136	12,161	23,297	20.92
TX	191	0.95	182	1,913	1,377	3,290	17.20
VA	442	0.95	420	4,420	3,182	7,602	17.20
WV	17	0.95	16	167	120	287	17.20
WI	1,403	0.95	1,332	14,025	10,098	24,123	17.20
Total/Average	**67,739**	**1.03**	**69,714**	**677,386**	**638,008**	**1,315,394**	**18.17**

[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 2006

State	RR soybean acreage	Herbicide application 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	152	2	1	1	608
AR	2,861	2	1	1	11,445
DE	162	2	1	1	648
FL	7	2	2	0	0
GA	140	2	1	1	558
IL	8,787	2	1	1	35,148
IN	5,244	2	1	1	20,976
IA	9,237	2	2	0	0
KS	2,678	2	1	1	10,710
KY	828	1	1	0	0
LA	861	2	1	1	3,445
MD	423	1	1	0	0
MI	1,700	2	1	1	6,800
MN	6,468	2	1	1	25,872
MS	1,603	2	2	0	0
MO	4,790	2	2	0	0
NE	4,545	1	1	0	0
NJ	79	2	1	1	317
NY	190	1	1	0	0
NC	1,233	2	1	1	4,932
ND	3,510	1	1	0	0
OH	4,185	2	2	0	0
OK	295	2	1	1	1,178
PA	366	2	1	1	1,462
SC	360	2	1	1	1,440
SD	3,871	2	1	1	15,484
TN	1,114	2	2	0	0
TX	191	2	1	1	765
VA	442	2	1	1	1,768
WV	17	2	1	1	67
WI	1,403	1	1	0	0
Total/Average	**67,739**	**1.81**	**1.19**	**0.61**	**143,622**

[1]Based on data from Table 6.3.

[2]Based on data from Table 6.4.

[3]Herbicide application costs = $4.00/acre, 2005.

Table 6.7. Aggregate impacts of glyphosate-resistant (RR) soybean in 2006.

State	RR soybean acreage	Changes in			
		Production costs		Herbicide use	
	000A	$/A	000$[1]	lb ai/A	000 lb
AL	152	-26.30	-3,998	-0.81	-122
AR	2,861	-26.30	-75,250	-0.81	-2,303
DE	162	-37.14	-6,017	-0.87	-141
FL	7	-6.70	-45	-0.45	-3
GA	140	-8.67	-1,209	-0.44	-61
IL	8,787	-25.65	-225,387	-0.72	-6,327
IN	5,244	-28.50	-149,454	-1.45	-7,620
IA	9,237	-18.89	-174,477	0.22	2,032
KS	2,678	-21.00	-56,228	-0.41	-1,100
KY	828	-10.90	-9,025	0.59	484
LA	861	-26.30	-22,652	-0.81	-693
MD	423	-18.10	-7,656	-0.69	-293
MI	1,700	-25.65	-43,605	-0.72	-1,224
MN	6,468	-31.90	-206,329	-0.86	-5,530
MS	1,603	-25.91	-41,539	-0.38	-604
MO	4,790	-21.93	-105,034	-0.23	-1,102
NE	4,545	-15.05	-68,402	-0.37	-1,659
NJ	79	-37.14	-2,941	-0.87	-69
NY	190	-26.10	-4,959	-1.07	-204
NC	1,233	-26.30	-32,428	-0.81	-993
ND	3,510	-19.30	-67,743	0.67	2,355
OH	4,185	-21.73	-90,940	1.00	4,164
OK	295	-27.45	-8,084	-1.02	-299
PA	366	-27.48	-10,044	-0.88	-322
SC	360	-16.27	-5,857	0.11	41
SD	3,871	-21.00	-81,291	-0.41	-1,591
TN	1,114	-21.02	-23,408	0.20	217
TX	191	-19.25	-3,682	-1.05	-201
VA	442	-14.61	-6,458	-1.44	-636
WV	17	-11.74	-196	-1.41	-24
WI	1,403	-19.40	-27,209	0.54	752
Total/Average	**67,739**	**-22.05**	**-1,561,545**	**-0.50**	**-23,075**

[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 acreage in the United States[1].

U.S. soybean acreage	1995	1996	1997	1998	2000	2002	2004
	Million acres						
Total	58.8	60.6	65.1	66.6	70	69.8	71.42
No-till	15.9	16.2	17.9	19	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

[1]Data is not available for 1999.

Source: Conservation Technology Information Center.

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Insect-resistant crops

Three applications of Bt corn (YieldGard Corn Borer, Herculex I, and YieldGard RW) and two applications of Cotton (Bollgard and Bollgard II) were in commercial production in 2005 and 2004. Implications for yields and costs were calculated for all the Bt applications except Herculex I in this report, as was the case for the 2005 report.

Since the first plantings of insect resistant Bt crops, growers have noted that the most substantial impacts have been improvements in crop yields. Unlike conventional insecticides, Bt crops offered in-build season long, and enhanced pest protection which translates into gains in yields. Still another significant impact of insect-resistant crops has been the reduction in insecticide use targeted to key pests, because the Bt crops have eliminated the need for insecticide applications.

Reductions in insecticide use and the number of insecticide sprays have led to reductions in input costs for adaptors of Bt crops. Other benefits of Bt crops have included reduced scouting costs, decreased pesticide exposure to applicators, and reduced energy use. The more specific agronomic and economic impacts from Bt crops for the 2006 crop season are identified and discussed in the following sections.

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

Two varieties of biotechnology-derived corn have provided protection against European corn borer and the Southwestern corn borer since 2003. These include YieldGard Corn Borer, which was planted to approximately 21 percent of total planted acreage in 2006. This is a reduction to that reported in 2005, where 34 percent of planted acres were estimated to have been planted to YieldGard Corn Borer varieties. The source of the 2006 information was Doane's 2006 Corn TraitTrak Data. Herculex I corn was estimated by the crop specialists as being planted to about 5 percent of the total planted acreage. In view of the fact that these data are not available by state, we will restrict the discussion to Yield Gard Corn Borer varieties only.

Thirty three states planted 16,602,689 acres of YieldGard Corn Borer corn in 2006. Note from Table 7.1 that some states are excluded from the data source mentioned above, including Arizona and Washington. Highest percentages of planted acres adopting YieldGard Corn Borer varieties were Alabama, Arkansas, Colorado, North Dakota, and South Dakota - in each case planted acres were above 30 percent (Table 7.1). Note again that because we used a different source for the data there is a major drop in the acres planted to YieldGard Corn Borer varieties. The reported planted acres for 2005 in this report were 34 percent or about 27.9 million acres.

Attractiveness of YieldGard Corn Borer varieties are related to the fact that they are called a "stacked" product for pest management. That is, the YieldGard Plus trait, which is the stacked product of YieldGard Corn Borer and YieldGard RW (root worm) was available for commercial planting in 2005. In addition to YieldGard Plus, a triple stacked product YieldGard Plus with Roundup Ready 2 Corn technology was as well available in limited quantities in 2005 and 2006. Case study 7 represents the impacts of European Corn Borer and Southwestern Corn Borer control resulting from the use of YieldGard Corn Borer varieties.

YieldGard Corn Borer impact estimates for 2006 were calculated using the same method used in earlier reports. Yield impacts due to corn borer were estimated based on the premise that high infestations usually lead to significant losses while low infestations do not affect yields. Information of corn borer on yields during low and high infestations was obtained from the 2001 report. This information was a result of a special 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 2002). Yield losses in high infestation years are typically much higher in the Plains states and in states were the Southwestern Corn Borer is the primary pest (Colorado, Kansas, Oklahoma, Kentucky and Texas). Alabama is the only state where no yield loss typically occurs due to corn borers. All years were classified with low infestation which according to the method of estimation means that no yield loss was evident.

Table 7.3 provides the state by state estimates of the aggregate impacts on total corn production, value of corn production, 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 corn borer control. Growers who use Bt corn are assumed to gain 100 percent of the lost yield due to corn borer infestation. Based on the comparisons to an untreated scenario, total production increases on current Bt is estimated to range between $116,142,000 and $625,671,000. A $3.01 per bushel annual price of corn was used in these calculations, obtained from NASS. YieldGard Corn Borer technology was assumed to cost $7 per acre, which was subtracted from the high and low year figures. Note that at an acreage of 16,591,736 the per acre cost saving is approximately $10 per acre in the low years and $39 in the high years. These estimates are higher than those for 2005 even though the use of YieldGard Corn Borer was lower due to the higher corn price. The price used for the conversions in 2005 was $1.95 per bushel.

Simulations involving the use of insecticides on current Bt corm acreage are presented in Table 7.4. The table shows state by state estimates of potential per acre yield and value that resulted from using insecticides in high infestation years. Insecticides provide 80 percent control of Corn Borers at an average cost of $14 per acre. Insecticide use was simulated for only high infestation years, since in low years the value of the use of Bt corn is not above the cost on average. Minnesota was the only state in 2006 that the value in # per acre was negative. The total value of this simulated response was $361,166,000.

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 cost 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 the use of insecticides (Table 7.4). Thus, in a high year, growers gain an extra 20 percent yield from Bt corn which they would not have gained using insecticides. Bt corn is credited with lowering production costs during high infestation years because Bt corn costs less than the insecticides.

New production volume, value and production cost estimates for low and high infestation 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 infestation 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 10. 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 16,591,736 in 2006, it was calculated that the Bt corn resulted in an increased production of 65,101,000 bushels valued at approximately $3 per bushel or $195 million dollars. Net returns from Bt corn were estimated to be about $185 million. Insecticide use was reduced by 2.8 billion pounds. The results from this simulation, although limited, show that the Bt corn has societal and producer value. Again, the use of Bt corn was lower than in 2005 but the price of corn was more than $1 higher, giving results for total corn production that are quite similar.

Table 7.1. Adoption of YieldGard Corn Borer corn in the United States in 2006

State	Planted corn acreage[1]	Acres planted to YieldGard Corn Borer corn[2]	Adoption of YieldGard Corn Borer corn
	000A	Acres	%
AL	230	76,472	33
AR	170	49,260	29
AZ[3]	55		
CA	540	793	0.1
CO	1,000	195,324	20
DE	165	57,010	35
GA	280	51,035	18
ID	270	13,193	5
IL	11,600	2,360,383	20
IN	5,500	570,921	10
IA	12,700	2,432,506	19
KS	3,400	1,077,481	32
KY	1,200	48,106	4
LA	300	20,725	7
MD	480	129,618	27
MI	2,200	267,346	12
MN	7,300	2,506,901	34
MS	300	22,932	8
MO	2,750	290,606	11
NE	8,300	2,001,516	24
NM	130	10,684	8
NY	970	166,078	17
NC	740	90,783	12
ND	1,750	677,859	39
OH	3,300	284,682	9
OK	310	117,104	38
PA	1,350	137,751	10
SC	300	4,720	2
SD	4,400	1,813,244	41
TN	600	31,577	5
TX	1,750	389,026	22
VA	510	64,777	13
WA[3]	130		
WI	3,750	632,116	17
WY	90	10,160	11
Total	**78,820**	**16,602,689**	**21**
U.S. Total/Average	**79,366**	**16,602,689**	**21**

[1]Source: National Agricultural Statistics Service, 2006 Acreage.
[2]Source: dmrkynetec, 2006 Corn TraitTrak Data.
[3]State was not included in the dmrkynetec data for 2006.

Table 7.2. Corn borer incidence and yield impacts 2005.[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 NCFAP 2002 report (Gianessi, et al., 2002).
[3]Based on assumptions from neighboring corn-producing state.

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	
	Acres	Low	High	Low	High	Low	High	Low	High	000 $/Year	Low	High
		Bu/A		000 Bu/Year		$/A		000$/Year			000 $/Year	
AL	76,472	0.0	8.0	0	612	0.00	24.08	0	1,841	535	-535	1,306
AR	49,260	5.0	30.0	246	1,478	15.05	90.30	741	4,448	345	397	4,103
CO	195,324	7.0	23.0	1,367	4,492	21.07	69.23	4,115	13,522	1,367	2,748	12,155
DE	57,010	3.9	11.2	222	639	11.74	33.71	669	1,922	399	270	1,523
GA	51,035	5.0	11.0	255	561	15.05	33.11	768	1,690	357	411	1,333
ID	13,193	7.0	23.0	92	303	21.07	69.23	278	913	92	186	821
IL	2,360,383	4.0	10.0	9,442	23,604	12.04	30.10	28,419	71,048	16,523	11,896	54,525
IN	570,921	3.0	7.0	1,713	3,996	9.03	21.07	5,155	12,029	3,996	1,159	8,033
IA	2,432,506	5.0	11.0	12,163	26,758	15.05	33.11	36,609	80,540	17,028	19,582	63,513
KS	1,077,481	5.0	40.0	5,387	43,099	15.05	120.40	16,216	129,729	7,542	8,674	122,186
KY	48,106	2.2	18.9	106	909	6.62	56.89	319	2,737	337	-18	2,400
LA	20,725	4.0	30.0	83	622	12.04	90.30	250	1,871	145	104	1,726
MD	129,618	8.0	26.0	1,037	3,370	24.08	78.26	3,121	10,144	907	2,214	9,237
MI	267,346	4.0	12.0	1,069	3,208	12.04	36.12	3,219	9,657	1,871	1,347	7,785
MN	2,506,901	4.5	13.0	11,281	32,590	13.55	39.13	33,956	98,095	17,548	16,408	80,547
MS	22,932	2.5	5.5	57	126	7.53	16.56	173	380	161	12	219
MO	290,606	5.0	30.0	1,453	8,718	15.05	90.30	4,374	26,242	2,034	2,339	24,207
NE	2,001,516	5.0	11.0	10,008	22,017	15.05	33.11	30,123	66,270	14,011	16,112	52,260
NM	10,684	7.0	23.0	75	246	21.07	69.23	225	740	75	150	665
NY	166,078	3.0	11.0	498	1,827	9.03	33.11	1,500	5,499	1,163	337	4,336
NC	90,783	5.0	11.0	454	999	15.05	33.11	1,366	3,006	635	731	2,370
ND	677,859	5.0	11.0	3,389	7,456	15.05	33.11	10,202	22,444	4,745	5,457	17,699
OH	284,682	2.0	12.0	569	3,416	6.02	36.12	1,714	10,283	1,993	-279	8,290
OK	117,104	8.0	18.0	937	2,108	24.08	54.18	2,820	6,345	820	2,000	5,525
PA	137,751	3.3	11.5	455	1,584	9.93	34.62	1,368	4,768	964	404	3,804
SC	4,720	3.0	10.0	14	47	9.03	30.10	43	142	33	10	109
SD	1,813,244	5.0	15.0	9,066	27,199	15.05	45.15	27,289	81,868	12,693	14,597	69,175
TN	31,577	5.0	11.0	158	347	15.05	33.11	475	1,046	221	254	824
TX	389,026	8.0	40.0	3,112	15,561	24.08	120.40	9,368	46,839	2,723	6,645	44,116
VA	64,777	3.0	15.0	194	972	9.03	45.15	585	2,925	453	131	2,471
WI	632,116	4.0	12.0	2,528	7,585	12.04	36.12	7,611	22,832	4,425	3,186	18,407
Total	**16,591,736**			**77,432**	**246,449**			**233,070**	**741,813**	**116,142**	**116,928**	**625,671**

[1]Compared to an untreated scenario.
[2]Arizona, California, Washington, and Wyoming are not included in the analysis.
[3]Calculated at $3.01/bushel (Source: NASS, Prices Received by Farmers, Corn, US. www.nass.usda.gov/Charts_and__Maps/).
[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	76,472	6.4	489	19.26	1,473	1,071	5.26	403	29,059
AR	49,260	24.0	1,182	72.24	3,559	690	58.24	2,869	18,719
CO	195,324	18.4	3,594	55.38	10,818	2,735	41.38	8,083	74,223
DE	57,010	9.0	511	26.97	1,538	798	12.97	739	21,664
GA	51,035	8.8	449	26.49	1,352	714	12.49	637	19,393
ID	13,193	18.4	243	55.38	731	185	41.38	546	5,013
IL	2,360,383	8.0	18,883	24.08	56,838	33,045	10.08	23,793	896,946
IN	570,921	5.6	3,197	16.86	9,623	7,993	2.86	1,631	216,950
IA	2,432,506	8.8	21,406	26.49	64,432	34,055	12.49	30,377	924,352
KS	1,077,481	32.0	34,479	96.32	103,783	15,085	82.32	88,698	409,443
KY	48,106	15.1	727	45.51	2,189	673	31.51	1,516	18,280
LA	20,725	24.0	497	72.24	1,497	290	58.24	1,207	7,876
MD	129,618	20.8	2,696	62.61	8,115	1,815	48.61	6,300	49,255
MI	267,346	9.6	2,567	28.90	7,725	3,743	14.90	3,982	101,591
MN	2,506,901	10.4	26,072	31.30	78,476	35,097	17.30	43,379	952,622
MS	22,932	4.4	101	13.24	304	321	-0.76	-17	8,714
MO	290,606	24.0	6,975	72.24	20,993	4,068	58.24	16,925	110,430
NE	2,001,516	8.8	17,613	26.49	53,016	28,021	12.49	24,995	760,576
NM	10,684	18.4	197	55.38	592	150	41.38	442	4,060
NY	166,078	8.8	1,461	26.49	4,399	2,325	12.49	2,074	63,110
NC	90,783	8.8	799	26.49	2,405	1,271	12.49	1,134	34,498
ND	677,859	8.8	5,965	26.49	17,955	9,490	12.49	8,465	257,586
OH	284,682	9.6	2,733	28.90	8,226	3,986	14.90	4,241	108,179
OK	117,104	14.4	1,686	43.34	5,076	1,639	29.34	3,436	44,500
PA	137,751	9.2	1,267	27.69	3,815	1,929	13.69	1,886	52,345
SC	4,720	8.0	38	24.08	114	66	10.08	48	1,794
SD	1,813,244	12.0	21,759	36.12	65,494	25,385	22.12	40,109	689,033
TN	31,577	8.8	278	26.49	836	442	12.49	394	11,999
TX	389,026	32.0	12,449	96.32	37,471	5,446	82.32	32,025	147,830
VA	64,777	12.0	777	36.12	2,340	907	22.12	1,433	24,615
WI	632,116	9.6	6,068	28.90	18,266	8,850	14.90	9,416	240,204
Total	**16,591,736**		**197,160**		**593,450**	**232,284**		**361,166**	**6,304,860**

[1]Calculated at 80% of the increase attributed to Bt corn, 2005.
[2]Calculated at $3.01/Bushel, 2005.
[3]Calculated at $14 /Acre, 2005.
[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	122	0	0	368	0	535	-535	535	-535	0
AR	5	5	246	296	271	741	890	815	345	-345	0	815	9,359
CO	5	5	1,367	898	1,133	4,115	2,704	3,410	1,367	-1,367	0	3,410	37,112
DE	5	5	222	128	175	669	384	527	399	-399	0	527	10,832
GA	9	1	255	112	241	768	338	725	357	-357	286	439	1,939
ID	5	5	92	61	77	278	183	230	92	-92	0	230	2,507
IL	5	5	9,442	4,721	7,081	28,419	14,210	21,314	16,523	-16,523	0	21,314	448,473
IN	6	4	1,713	799	1,347	5,155	2,406	4,056	3,996	-3,996	799	3,256	86,780
IA	5	5	12,163	5,352	8,757	36,609	16,108	26,359	17,028	-17,028	0	26,359	462,176
KS	5	5	5,387	8,620	7,004	16,216	25,946	21,081	7,542	-7,542	0	21,081	204,721
KY	5	5	106	182	144	319	547	433	337	-337	0	433	9,140
LA	7	3	83	124	95	250	374	287	145	-145	58	229	2,363
MD	6	4	1,037	674	892	3,121	2,029	2,684	907	-907	181	2,503	19,702
MI	3	7	1,069	642	770	3,219	1,931	2,318	1,871	-1,871	-749	3,066	71,114
MN	6	4	11,281	6,518	9,376	33,956	19,619	28,221	17,548	-17,548	3,510	24,712	381,049
MS	5	5	57	25	41	173	76	124	161	-161	0	124	4,357
MO	5	5	1,453	1,744	1,598	4,374	5,248	4,811	2,034	-2,034	0	4,811	55,215
NE	7	3	10,008	4,403	8,326	30,123	13,254	25,062	14,011	-14,011	5,604	19,458	228,173
NM	5	5	75	49	62	225	148	187	75	-75	0	187	2,030
NY	5	5	498	365	432	1,500	1,100	1,300	1,163	-1,163	0	1,300	31,555
NC	2	8	454	200	251	1,366	601	754	635	-635	-381	1,135	27,598
ND	7	3	3,389	1,491	2,820	10,202	4,489	8,488	4,745	-4,745	1,898	6,590	77,276
OH	8	2	569	683	592	1,714	2,057	1,782	1,993	-1,993	1,196	587	21,636
OK	5	5	937	422	679	2,820	1,269	2,044	820	-820	0	2,044	22,250
PA	7	3	455	317	413	1,368	954	1,244	964	-964	386	858	15,704
SC	8	2	14	9	13	43	28	40	33	-33	20	20	359
SD	5	5	9,066	5,440	7,253	27,289	16,374	21,831	12,693	-12,693	0	21,831	344,516
TN	7	3	158	69	131	475	209	395	221	-221	88	307	3,600
TX	2	8	3,112	3,112	3,112	9,368	9,368	9,368	2,723	-2,723	-1,634	11,002	118,264
VA	9	1	194	194	194	585	585	585	453	-453	363	222	2,462
WI	3	7	2,528	1,517	1,820	7,611	4,566	5,480	4,425	-4,425	-1,770	7,250	168,143
Total			**77,432**	**49,290**	**65,101**	**233,070**	**148,363**	**195,955**	**116,142**	**-116,142**	**10,390**	**185,565**	**2,870,403**

[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.

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

2006 was the fourth year of commercial planting of YieldGard RW corn. US Corn growers planted YieldGard RW hybrids on approximately 7.7 million acres in 2006, up from 3.51 million acres in 2005. The 2006 plantings represented about 10 percent of total planted acres. Planted acres were highest in Iowa, Minnesota and Illinois in terms of total acres and represented 11, 16 and 17 percent of planted acres, respectively. The highest percent of acres planted was in Mississippi at 26 percent (Table 8.1).

Reasons for the comparatively rapid increase in YieldGard RW corn, essentially doubling every year for the past three years, is the fact that the technology is currently available in hybrids suitable to various regions of the Corn Belt. Additionally, YieldGard RW is available in stacked products with YieldGard Corn Borer and Roundup Ready 2 Corn. Finally, as of August 8, 2005, the European Union approved the use of YieldGard RW corn for use in animal feed. These factors in general have lead to the rapid increase in planted acres to YieldGard RW corn.

The survey of rootworm research is in Sankula 2005, and shows that the isolation of the trait has significant yield improvement potential. It out performs standard insecticides and was shown in infested areas to protect the roots of corn planted commercially. Research on yield improvements is now forthcoming and has as well been summarized by Sankula 2005. This research is mostly for Corn Belt states and indicates an increase in yields of 15-20 percent. Of course corn yields are higher in the Corn Belt than in other states. For a common value of yield increase we assumed 5 percent in this analysis.

Table 8.2 provides information on changes in crop production and production value due to YieldGard RW hybrids. Based on a 5 percent gain in yields, YieldGard RW increased corn production by 3.275 million pounds in 2006. The market value of the increased production at $3.01 per bushel is $177,000. These numbers are likely low due to the fact that most of the acres planted were in the Corn Belt.

Insecticide treatments for rootworm are available and used. Growers use both seed treatments (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 larva control on conventional corn plantings. Seed treatments for rootworm are relatively new and were first approved and marketed in 1999. The insecticides most commonly applied for control of corn rootworm are chlorethoxyfos, chlorpyriphos, terbufos, tebupirimphos + cyfluthrin, bifenthrin fipronil, and tefluthrin.

A survey of corn entomologists indicated that on average growers applied 0.51 pounds ai/acre of insecticides at a cost of $15 per acre in 2005 (Sankula 2006). Based on this information, it was assumed that growers that planted YieldGard RW corn hybrids in 2006 would have applied 3.9 million pounds less insecticide in 2006. YieldGard RW corn growers spent $14 per acre in 2006 to gain access to YieldGard RW corn hybrids.(Krupke 2006, Rice 2006 and Steffey 2006). Therefore the adoption costs were $107,633,000 for 7,688,000 acres planted. However, the net economic gain due to increases in crop production and decrease in insecticide use and spray was $184,520,000.

In spite of the use of YieldGard RW corn hybrids, insecticide treatments may still be needed to lessen the risk of damage cause by secondary pests like wireworms, white grubs, flea beetles, and seed corn maggots especially if their frequency of occurrence increases. Monsanto requires YieldGard RW to be treated with an insecticide for control of secondary pests. Currently, thiametthoxam and clothianilin are used as treatments for secondary pests. 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 n 2006.

Now, several rootworm resistant varieties are coming on to the market, indicating that the use of rootworm resistant varieties will increase more rapidly in the future. Many of these are stacked for prevention of other pests, as well as some of the secondary pests mentioned above. Names of these alternative rootworm-resistant varieties are Herculex RW, Herculex XTRA and MIR604 which received registration in October of 2006.

Table 8.1. Adoption of Yield Gard RW corn in 2006.

State	Planted acres[1]	Adoption of YieldGard corn[2]	YieldGard RW corn acreage
	000A	%	000Acres
CO	1,000	18	178
DE	165	3	5
IL	11,600	17	1,958
IN	5,500	9	500
IA	12,700	11	1,458
KS	3,400	4	141
KY	1,200	0	2
MD[3]	480		
MI	2,200	6	132
MN	7,300	16	1,164
MS	300	26	77
NE	8,300	6	511
NY	970	15	148
NC	740	1	7
ND	1,750	0	8
OH	3,300	6	195
OK	310	6	18
PA	1,350	6	77
SD	4,400	12	546
TN[3]	600		
TX	1,750	12	216
VA	510	0	2
WI	3,750	9	343
Total/Average	**73,575**	**10.4**	**7,688**
U.S. Total/Average	**79,366**	**9.7**	**7,688**

[1]Source: National Agricultural Statistics Service, 2006 Acreage.

[2]Source: dmrkynetec, 2006 Corn TraitTrak Data.

[3]State was not included in the dmrkynetec data.

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

State[1]	Corn yield in 2006[2]	Yield gain due to YieldGard RW corn[3]		Value of gained production[4]	YieldGard RW corn acreage	Yield gain due to YieldGard RW corn	Value of gained production from Bt acreage
	BU/A	Bu/A	lb/A	$/A	Acres	000lb	000$
CO	156	7.8	437	23.59	0	78	4
DE	145	7.3	406	21.92	0	2	0
IL	163	8.2	456	24.65	2	894	48
IN	157	7.9	440	23.74	1	220	12
IA	166	8.3	465	25.10	1	678	37
KS	115	5.8	322	17.39	0	46	2
KY	146	7.3	409	22.08	0	1	0
MI	147	7.4	412	22.23	0	55	3
MN	161	8.1	451	24.34	1	525	28
MS	110	5.5	308	16.63	0	24	1
NE	152	7.6	426	22.98	1	218	12
NY	129	6.5	361	19.50	0	53	3
NC	132	6.6	370	19.96	0	3	0
ND	111	5.6	311	16.78	0	2	0
OH	159	8.0	445	24.04	0	87	5
OK	105	5.3	294	15.88	0	5	0
PA	122	6.1	342	18.45	0	26	1
SD	97	4.9	272	14.67	1	148	8
TX	121	6.1	339	18.30	0	73	4
VA	120	6.0	336	18.14	0	1	0
WI	143	7.2	400	21.62	0	137	7
Total/Average	**124**	**6.2**	**348**	**18.78**	**8**	**3,275**	**177**

[1]Maryland and Tennessee are not included in the analysis.
[2]Source: USDA-Quick Stats, Crops. www.nass.usda.gov.
[3]A 5% yield gain was assumed due to the planting of YieldGard RW corn.
[4]Approximate selling price of corn in 2006 = $3.01/bushel or 5.4¢/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
CO	178	77,785	4,200	2,493	2,671	4,378	90,821
DE	5	1,840	99	63	68	104	2,312
IL	1,958	893,706	48,260	27,414	29,372	50,218	998,664
IN	500	219,844	11,872	7,001	7,501	12,372	255,050
IA	1,458	677,507	36,585	20,407	21,864	38,043	743,392
KS	141	45,527	2,458	1,979	2,121	2,600	72,108
KN	2	1,008	54	35	37	57	1,257
MI	132	54,534	2,945	1,855	1,987	3,077	67,571
NM	1,164	524,776	28,338	16,297	17,462	29,502	593,691
MS	77	23,590	1,274	1,072	1,149	1,350	39,061
NE	511	217,557	11,748	7,156	7,668	12,259	260,701
NY	148	53,498	2,889	2,074	2,222	3,037	75,538
NC	7	2,567	139	97	104	146	3,542
ND	8	2,433	131	110	117	139	3,992
OH	195	87,006	4,698	2,736	2,931	4,894	99,670
OK	18	5,269	285	251	269	302	9,140
PA	77	26,402	1,426	1,082	1,159	1,503	39,417
SD	546	148,183	8,002	7,638	8,184	8,547	278,252
TX	216	73,344	3,961	3,031	3,247	4,177	110,405
VA	2	802	43	33	36	46	1,218
WI	343	137,489	7,424	4,807	5,151	7,768	175,123
Total	**7,688**	**3,274,667**	**176,832**	**107,633**	**115,321**	**184,520**	**3,920,924**

[1]Calculations on crop yield and value were detailed in Table 8.2.
[2]Adoption costs for Yield Gard RW corn in 2006 = $14/A.
[3]Average cost of insecticides used for rootworm control in 2006 = $15/A
[4]Average insecticide use rate for rootworm control = .051 lb ai/A.

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9. Bollgard cotton (IR-III)

Bollgard cotton was planted to about 7.40 million acres in 2006, down from 7.78 acres in 2005 (Table 9.1 and Sankula 2006). On a percent basis this figure for acreage represents about 49 percent of total cotton acreage. Thus cotton acreage was up in 2006 from 14.25 million acres in 2005 to 15.27 million acres, but the use of Bollgard cotton varieties was down about 300 thousand acres or 1 percent. States with the highest percentage of planted acres relative to total state acres were Alabama, Arkansas, Florida, Georgia, Mississippi, Louisiana, North Carolina, and Tennessee. The low adoption state was again California.

Bollworm and the bollworm pest complex were again ranked as the number one pest problem in cotton as before in 2005 and pervious years. Of the total cotton crop, the bollworm/bollworm complex reduced yields by about 0.9 percent, the lowest in recent years (Williams 2007). The use of Bollgard cotton varieties was credited with the reduction in this pest, the lowest impact in several years. The impact of Bollgard is not only in increased yields but in reduced sprayings and lower amounts of active ingredients on cotton acreage.

Adoption costs of Bollgard cotton were again taken from Williams 2007, and are presented in Table 9.2. Aggregate impacts of Bollgard cotton are reported in Table 9.3. The analysis indicates that Bollgard cotton plantings in 2006 were associated with significantly higher lint yields and lower pesticide use in all cotton producing states (Table 9.3). Seed costs for Bollgard cotton were at a slight premium, ranging from approximately $15-$35 per acre (Table 9.2).

The increase in production of lint due to Bollgard was 604 million pounds with a value of approximately 260 million dollars. The reduction in sprays was about 7 thousand and the reduced insecticide use was 1.9 million pounds of active ingredients. These are remarkable savings for producers and important environmental benefits of the Bollgrad varieties. Adoption costs of Bollgard varieties were calculated from the information in Table 9.2 and are estimated at $128. The value of the Bollgard varieties is then estimated at 243 million dollars. Table 9.4 gives the average number of applications and the number of acres of Bollgard cotton sprayed to control bollworms. Compared to the non-bollworm cotton varieties these sprayings are minimal.

One last observation was gained from the reading of a paper by Walt Mullins, et.al. from the Cotton Conference in 2005. He said that is really not fair to compare today's cotton to Bt (Bollgard) cotton. He feels that the conventional cotton is being protected by the Bt cotton, that the Bt acres are having a halo effect. He thought it would be better to compare conventional cotton planted prior to the introduction of Bt cotton to today's Bt cotton. This paper was prepared in 2005, so we called him to determine if he still felt that the same effects were spread to conventional cotton, and he assured us that his evaluation had not changed.

The Bt varieties are in fact changing the threat of pests as well as saving cotton. This implies that the pest system is being changed and this may be a further impact of Bt cotton and perhaps other Bt varieties for other crops. In short, the Bt varieties are having an unintended impact on the threat of pests. This does not take away from an impact mentioned earlier, the certainty factor which in this analysis has not been treated. There is significant value to producers of the certainty of having a bollworm free cotton crop. The analysis of this would take us to calculations of risk preferences but risk aversion is a real factor in influencing adoption.

Table 9.1. Adoption of Bollgard cotton in the U.S. in 2006.

State	Planted acreage[1]	Bollgard cotton adoption[2]	
	000 Acres	% of total[2]	000 Acres
AL	575	85.94	494
AZ	197	61.00	120
AK	1,170	81.87	958
CA	560	9.03	51
FL	103	86.18	89
GA	1,400	92.51	1,295
KS	115	9.33	11
LA	635	83.19	528
MS	1,230	79.43	977
MO	500	70.11	351
NM	63	19.19	12
NC	870	82.14	715
OK	320	26.63	85
SC	300	75.49	226
TN	700	86.32	604
TX	6,431	13.87	892
VA	105	53.11	56
Total/Average	**15,274**	**49**	**7,464**

[1]Source: National Agricultural Statistics Service, Quick Stats, Crops, Cotton.
[2]Based on the 2006 Cotton Planting Data from the U.S. Agricultural Marketing Service.

Table 9.2. Adoption costs for Bollgard cotton in the United States in 2006.

State	Planted Bollgard cotton acreage[1]	Bollgard cotton seed costs	
	000 Acres	$/acre[2]	000$
AL	494	23	11,366
AZ	120	34	4,086
AR	958	20	19,158
CA	51	15	759
FL	89	28	2,485
GA	1,295	19	24,608
KS[3]	11	17	182
LA	528	15	7,924
MS	977	20	19,540
MO	351	20	7,011
NM	12	22	266
NC	715	12	8,575
OK	85	9	767
SC	226	10	2,265
TN	604	13	7,855
TX	892	16	14,272
VA	56	22	1,227
Total/Average	**7,464**	**19**	**132,344**

[1]From Table 9.1.

[2]Source: M. Williams , 2007.

[3]$/acre based on an average of nearby states.

Table 9.3. Aggregate impacts of Bollgard cotton in 2006.[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	000lb	000$	#	000lb	000$	000$	000$
AL	494	40,027	17,211	460	124	7,294	11,366	13,140
AZ	120	9,734	4,186	112	30	1,774	4,086	1,873
AR	958	77,588	33,363	891	239	14,138	19,158	28,344
CA	51	4,096	1,761	47	13	746	759	1,749
FL	89	7,190	3,092	83	22	1,310	2,485	1,916
GA	1,295	104,906	45,110	1,204	324	19,116	24,608	39,618
KS	11	869	374	10	3	158	182	350
LA	528	42,789	18,399	491	132	7,797	6,339	19,857
MS	977	79,136	34,029	909	244	14,420	19,540	28,909
MO	351	28,395	12,210	326	88	5,174	3,856	13,528
NM	12	979	421	11	3	178	266	334
NC	715	57,884	24,890	665	179	10,548	8,575	26,862
OK	85	6,902	2,968	79	21	1,258	767	3,459
SC	226	18,344	7,888	211	57	3,343	2,265	8,966
TN	604	48,943	21,046	562	151	8,919	7,855	22,109
TX	892	72,250	31,068	830	223	13,166	14,272	29,962
VA	56	4,517	1,942	52	14	823	1,227	1,539
Total	**7,464**	**604,550**	**259,957**	**6,941**	**1,866**	**110,162**	**127,605**	**242,514**

[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 lbs; 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 2006[1].

State	Bollworm applications to Bollgard cotton	Bollgard acreage sprayed for bollworm control
	#	Acres
AL	1.0	141,000
AZ	0.0	0
AR	1.8	700,000
CA	0.0	0
FL	1.0	2,000
GA	1.1	300,000
KS	0.0	0
LA	1.7	529,596
MS	1.0	654,500
MO	0.0	100
NM	1.0	3,400
NC	1.2	724,000
OK	1.0	5,000
SC	1.0	235,000
TN	1.4	457,000
TX	0.4	93,423
VA	1.0	85,000
Average/Total	**1.1**	**3,930,019**

[1]Source: M. Williams. , 2007.

References

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10. Bollgard II cotton (IR-IV)

Bollgard II cotton was planted to abut 1.337 million acres in 2006, up considerably from 2005 when 322,000 acres were planted, an increase of almost four times. This is about 0.9 percent of total acreage (Table 10.1). The application of Bollgard II was lower than Bollgard, since the trait is not as widely suitable is Bollgard. The increase in 2006 is related to the additional varieties of Bollgard II that have become available, and may explain the reduction of Bollgard planted as recorded in the previous case study (9). In fact, the differences in increases and decreases are very similar.

In 2006, Bollgard II cotton was planted in all states except Florida. This is an increase in the number of states in which it was planted in 2005. In 2005, the states where the Bollgard II was not available were California, Florida, Kansas, and Tennessee. The highest acreages were planted in New Mexico and Oklahoma, in excess of 60 percent.

The adoption costs for Bollgard II were about 1 dollar per acre higher than for Bollgard (Williams 2007). Again the range for costs was between about $15 and $35 per acre (Table 10.2). Impacts of Bollgard II are estimated in Table 10.3. In general, the insect spraying reduction is larger than with Bollgard cotton varieties. This shows up as well in Table 10.4, where the economic returns appear similar for Bollgrad II and Bollgard. The economic advantage for Bollgard II was about $70 million for 10 percent of the crop against the level for Bollgard - a value of $242 million, which is for just less that 50 percent of the crop. In short, Bollgard II seems to reduce spraying necessity and increase yields over Bollgard cotton.

On the surface Bollgard II seems the better Bt variety; however, more careful research is needed to verify this gross assertion, involving the yields in the states where available, impacts reflecting perhaps more productive early adopters, as well as other factors. It is clearly a new variety that has experienced rapid adoption.

Table 10.1. Adoption of Bollgard II cotton in the U.S. in 2006.

State	Planted acreage[1]	Bollgard II adoption[2]	
	000 Acres	% of total[2]	Acres
AL	575	1.51	8,683
AZ	197	37.09	73,067
AR	1,170	6.60	77,220
CA	560	2.67	14,952
FL	103	0	0
GA	1,400	1.09	15,260
KS	115	5.88	6,762
LA	635	8.75	55,563
MS	1,230	7.24	89,052
MO	500	16.98	84,900
NM	63	61.58	38,795
NC	870	8.26	71,862
OK	320	62.38	199,616
SC	300	16.60	49,800
TN	700	9.19	64,330
TX	6,431	7.55	485,541
VA	105	1.85	1,943
Total/Average	**15,274**	**15**	**1,337,345**

[1]Source: National Agricultural Statistics Service, 2006 Acreage.
[2]Based on the 2006 Cotton Planting Data from the U.S. Agricultural Marketing Service.

Table 10.2. Adoption costs for Bollgard II cotton in the United States in 2006.

State	Planted Bollgard cotton acreage[1]	Bollgard II seed costs	
	Acres	$/acre	000$
AL	8,683	24	208
AZ	73,067	35	2,557
AK	77,220	21	1,622
CA	14,952	16	239
FL	0	29	0
GA	15,260	20	305
KS[3]	6,762	18	122
LA	55,563	16	889
MS	89,052	21	1,870
MO	84,900	21	1,783
NM	38,795	23	892
NC	71,862	13	934
OK	199,616	10	1,996
SC	49,800	11	548
TN	64,330	14	901
TX	485,541	17	8,254
VA	1,943	23	45
Total/Average	**1,337,345**	**20**	**23,165**

[1]From Table 10.1.

[2]$/acre based on an average of nearby states.

Table 10.3. Aggregate impacts of Bollgard II cotton in 2006[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	000lb	000$	#	000lb	000$	000$	000$
AL	8,683	1,111	478	9,724	6	147	208	416
AZ	73,067	9,353	4,022	81,835	49	1,233	2,557	2,698
AK	77,220	9,884	4,250	86,486	52	1,303	1,622	3,932
CA	14,952	1,914	823	16,746	10	252	239	836
FL	0	0	0	0	0	0	0	0
GA	15,260	1,953	840	17,091	10	258	305	792
KS	6,762	866	372	7,573	5	114	122	365
LA	55,563	7,112	3,058	62,230	37	938	889	3,107
MS	89,052	11,399	4,901	99,738	60	1,503	1,870	4,535
MO	84,900	10,867	4,673	95,088	57	1,433	1,783	4,323
NM	38,795	4,966	2,135	43,451	26	655	892	1,898
NC	71,862	9,198	3,955	80,485	48	1,213	934	4,234
OK	199,616	25,551	10,987	223,570	134	3,370	1,996	12,360
SC	49,800	6,374	2,741	55,776	34	841	548	3,034
TN	64,330	8,234	3,541	72,050	43	1,086	901	3,726
TX	485,541	62,149	26,724	543,805	327	8,196	8,254	26,666
VA	1,943	249	107	2,176	1	33	45	95
Total	**1,337,345**	**171,180**	**73,607**	**1,497,826**	**900**	**22,574**	**23,165**	**73,016**

[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 = 1.12; reduction in insecticide and spray costs = $16.88/acre; gain in lint yields per acre = 128 lbs; net economic advantage/acre = $70.52; average cost of 1 lb of cotton lint in 2005 = $0.43; 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 9.2.

Table 10.4. Adoption of WideStrike cotton in the United States in 2006.

State	Planted acreage[1]	WideStrike adoption[2]	
	000 Acres	%	Acres
AR	1,170	0.36	4,212
GA	1,400	0.82	11,480
LA	635	0.97	6,160
MS	1,230	1.5	18,450
NM	63	13.64	8,593
NC	870	0.62	5,394
SC	300	0.39	1,170
TN	700	0.2	1,400
TX	6,431	0.46	29,583
VA	105	0.74	777
Total	**12,904**	**0.68**	**87,218**
U.S. Total	**15,274**	**0.57**	**87,218**

[1]Source: National Agricultural Statistics Service, Quick Stats, Crops, Cotton.

[2]Based on the 2006 Cotton Planting Data from the U.S. Agricultural Marketing Service.

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Conclusion

As was documented by Sankula 2006, every crop management decision has consequences, and the decision to plant biotechnology-derived crops is no exception. US growers have clearly made the decisions to plant the biotechnology-derived crops because they have realized significant benefits in terms of reduced production costs, limited applications of active ingredients from chemicals and improved yields. Confidence is growing among US farmers regarding the use of biotechnology-derived crops. And this may be fortunate relative to energy demands from many of these crops. In 2006 and 2007, corn and soybean experienced sharp increase in demand for use in energy production – in addition to feed and food use. The biotechnology-derived crops added to the reduction in world-wide prices due to their impacts for increased production. We see this as an added factor that will push the use of biotechnology-derived crops across the world in the future.

One aspect of the biotechnology-derived crops that has been alluded to several times in the text of this report is the fact that the calculations made in this report are likely serious under-estimates of the value of the crops to producers. Many producers, for example, do not own the land that they use for production. Moreover, producers borrow most of the funds for planting and growing the crops. To see the value of biotechnology-derived crops, think of the threat to producer solvency of not planting the biotechnology-derived crops and losing the crop to weeds or insects. These calculations relate the insurance value of the biotechnology-derived crops - in short, how much insurance would an operator of the type described pay to not lose the annual crop. Obviously it is something substantial, but a figure that has not been taken into consideration in this report.

Another issue that has surfaced in the report is what is called the halo effect of insecticides and insecticide resistant crops. There is good reason to believe that for some of the insecticide resistant crops, planting large acreages for several years will have the effect of changing the population dynamics of the insect population. For example, in the case of corn rootworm the infestations may go down if the rootworms have had to eat insect resistant crops in the field of reference for a long time. We know that crop rotations reduce the damage from root worms for similar reasons. Similar arguments can be made for corn borer and for bollworms. These aspects of the use of biotechnology-derived crops need to be further analyzed.

Finally, biotechnology-derived crops have addressed only the simplest of problems for crop growth. Cold tolerance and drought resistance are on the horizon. Flavor and shelf life are other issues that one would have to believe that will be addressed by biotechnology-derived crops. These traits have human health as well as survival benefits, and will be more rapidly adopted if available. In short, the future of biotechnology-derived crops looks bright to the authors and in an industry is ready to accept the new challenges suggested by past achievements.