Biotechnology-Derived Crops Planted in 2004 - Impacts on US Agriculture

December 2005

Sujatha Sankula Ph.D
Gregory Marmon
Edward Blumenthal

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

Biotechnology-Derived Crops Planted in 2004 - Impacts on US Agriculture

Key Findings

Biotechnology-derived crops continued to provide positive agronomic, economic, and environmental impacts in the United States in 2004, similar to years before. This is reflected in the continued increase in planted acreage of 118 million acres in 2004, compared to 106 million acres in 2003. The current study is an update to "Impact on US Agriculture of Biotechnology-Derived Crops Planted in 2003", which was released in 2004. Both studies evaluated the reasons behind the rapid adoption of these crops in the United States and analyzed the producer and crop production impacts that resulted from the widespread adoption of these crops.

American growers planted six biotechnology-derived crops, canola, corn, cotton, papaya, soybean, and squash, in 2004, as in 2003. Although the number of planted traits and applications remained the same, at three and eleven, respectively, in 2004, similar to 2003, expanded acreage of 11% has led to overall increase in crop yield, farm income and reduced pesticide use. The eleven planted applications in 2004 include herbicide-resistant canola, corn, cotton, and soybean; virus-resistant squash and papaya; three applications of insect-resistant corn, and two applications of insect-resistant cotton.

Production and economic impacts

Biotechnology-derived crops provided enhanced, season-long, and effective control of key pest problems in crop production thereby resulting in positive impacts. Combined impacts of the 11 biotechnology-derived applications demonstrated that crop production was enhanced by 6.6 billion pounds; crop production costs were decreased by $1.7 billion dollars; and pesticide use was lowered by 62.0 million pounds in 2004 (Table 1). Increased revenue from higher yields and reduced production costs improved net returns to growers by $2.3 billion in 2004. Compared with 2003, crop production improved by 24%; crop production costs decreased by 13%, net economic returns increased by 21%, and pesticide use reduced by an additional 34%. Impacts are estimated to increase further in the coming years, as more seed supplies are available for YieldGard Rootworm corn and Bollgard II cotton and as more crops such as Roundup Ready Flex cotton and Herculex RW corn, which have obtained regulatory clearance in 2005, will be available for commercial planting.

Table 1	**Overall impact on U.S. agriculture of biotechnology-derived crops**				
Year	**Planted acreage**	**Yield increase**	**Reduction in production costs**	**Net economic impact**	**Pesticide use reduction[1]**
	Million acres	Billion pounds	Billion dollars	Billion dollars	Million pounds
2004	118	6.61	1.7	2.3	62.0
2003	106	5.34	1.5	1.9	46.4
2001	80	3.79	1.2	1.5	45.7

[1] Refers to active ingredients.

Pesticide use impacts
The 11 applications of biotechnology-derived crops planted in 2004 reduced the use of pesticides in crop production by 62.0 million pounds. This represents a further 34% decrease in pesticide usage compared with 2003. Herbicide-resistant crops accounted for the largest reduction of pesticide use compared to other applications. Increased acreage of Liberty Link crops (canola, corn, and cotton) has contributed to further reductions in pesticide use in 2004. While herbicide-resistant soybean accounted for 36% of the reduction, herbicide-resistant corn and cotton contributed 30 and 23%, respectively. About 11% reduction in pesticide use was due to insect-resistant crops.

Crop impacts
The planting of biotechnology-derived varieties resulted in significant impacts in all the six crops evaluated in this study. While yield improvement and pesticide use reduction was greatest in biotechnology-derived field corn, planting of soybean led to largest reduction in production costs and greatest net economic impact. Both crops were leaders in the same categories in 2003.

Biotechnology-derived varieties improved corn production by 5.9 billion pounds in 2004. Cotton ranked second in yield improvement, with an additional 587 million pounds produced due to biotechnology-derived varieties. Biotechnology-derived soybean reduced production costs by $1.37 billion, and therefore increased growers' net returns by the same amount. Overall reduction in pesticide use due to biotechnology-derived varieties was greatest in corn (23.3 million pounds), followed by soybean (22.4 million pounds), and cotton (15.9 million pounds).

State impacts
The study documented significant benefits in the 43 states of the United States where biotechnology-derived crops were planted. In general, midwestern states of the United States experienced significant benefits in 2004, as in 2003, due to their large acreage of corn and soybean. Crop production gains were greatest in Nebraska (1.13 billion pounds) followed by Iowa (1.11 billion pounds). In fact, Nebraska and Iowa were the only two states that realized a production gain of over one billion pounds in 2004.

The largest reduction in production costs and greatest net economic impact occurred in Iowa ($218 million and $266 million, respectively). Estimates also indicate that crop production costs were reduced by at least $100 million or more in six states (Iowa, Indiana, Illinois, Minnesota, Missouri, and Texas) due to the planting of biotechnology-derived crops in 2004. While pesticide use reduction was greatest in Iowa (9.1 million pounds), Minnesota and Illinois ranked second and third, respectively, in the same category (8.1 and 7.4 million pounds, respectively). Overall, Iowa received the largest returns from biotechnology-derived crops in 2004.

Study Background and Purpose
American growers planted biotechnology-derived crops for the ninth consecutive year in 2004 with the same zeal and enthusiasm as in 1996, the first year of commercial planting of these crops. Benefits reaped from the technology have been the driving force in the

expansion of the planted acreage each year. American growers planted 118 million acres to biotechnology-derived crops in 2004, which represents 11% increase compared with acreage planted in 2003. Planted acreage of biotechnology-derived crops in 2004, as in 2003, was concentrated in six crops (canola, corn cotton, papaya, soybean, and squash) and three applications (herbicide-resistance, insect-resistance, and virus-resistance).

The purpose of the current study is to analyze, quantify, and document the agronomic, economic, and environmental impacts of biotechnology-derived crops on US agriculture. Two earlier reports by the National Center entitled "Plant biotechnology: current and potential impact for improving pest management in US agriculture" and "Impact on US Agriculture of Biotechnology-Derived Crops Planted in 2003" documented clear-cut benefits to growers in terms of improved crop yields, reduced production costs, and reduced pesticide use due to extensive planting of biotechnology-derived crops.

Since the last study, the number of acres planted to biotechnology-derived varieties increased by 12 million acres or 11%. In addition, glufosinate-resistant cotton was planted by the growers for the first time in 2004. The current study, therefore, focuses on calculating the impacts of these crops based on acreage and applications planted in 2004. Similar to the previous reports, the current study identified and quantified impacts on production volume, production value, production costs and pesticide use. Impacts of biotechnology-derived crops on other production practices such as tillage also were included.

Changes in production volume were measured based on yield changes that have occurred when biotechnology-derived crops replaced conventional crops. Similarly, change in production value was calculated based on the yield changes and crop prices. Changes in production costs were calculated by determining which current practices would be affected. Adoption costs associated with the use of the technology (either as technology fee or seed premium or both) were considered in the calculations. Finally, changes in pesticide use were quantified when the biotechnology-derived crop cultivar has replaced or substituted the current use of the target pesticides leading to either an increased or reduced usage. All the above impacts were calculated using 2004 acreage, for which the U.S. Department of Agriculture's National Agricultural Statistics Service served as a valuable resource.

University researchers and university Extension Crop Specialists were surveyed to obtain first hand information on the existing pest management approaches in conventional crops and to help determine how biotechnology-derived crops replaced or substituted current production practices. Updated estimates, contained within 11 case studies, were sent to relevant external reviewers for comment and their comments were integrated into the final report. In sum, 29 agriculture, pest management, and plant biotechnology experts from 21 academic and government institutions reviewed the report.

The full report containing all 11 case studies can be accessed at www.ncfap.org.

Adoption of Biotechnology-Derived Crops in 2004

Table 2 displays the information on the adoption of biotechnology-derived crops planted in 2004. In general, herbicide-resistant crops were planted on a large scale in 2004 compared with insect/virus-resistant crops. The adoption of insect/virus-resistant crops varies each year based on the anticipated level of infestation of target pests. Adoption of these crops, Bt crops in particular, will continue to increase in future, as new varieties such as Herculex RW corn were approved for planting in 2005 and as more seed supplies are available for YieldGard Rootworm and Bollgard II cotton, which were in their second year of planting in 2004.

In 2004, adoption of herbicide-resistant soybean was highest at 85 percent followed by herbicide-resistant cotton (77 percent), and herbicide-resistant canola (75 percent). Adoption of the new Bt varieties of corn (Herculex I and YieldGard Rootworm) and cotton (Bollgard II), which were introduced in 2003, was still low in 2004, at 2% or less, due to limited seed supplies. However, expansion in planted acreage was greatest for these new traits in 2004. Adoption of these new crop traits will increase significantly in the next few years once seed supply is abundant.

Table 2	**Adoption of biotechnology-derived crops in the United States in 2004**				
Case study	**Crop**	**Trait**	**Percentage adoption**		
			2004	**2003**	**2001**
1	Papaya	Virus-resistant	56	46	37
2	Squash[a]	Virus-resistant	10	3	17
3	Canola	Herbicide-resistant	75	75	70
4	Corn	Herbicide-resistant	18	14	8
5	Cotton	Herbicide-resistant	77	74	59
6	Soybean	Herbicide-resistant	85	82	69
7	Corn	Insect-resistant (IR-I)[b]	28	30	21
8	Corn	Insect-resistant (IR-II)[c]	2	0.6	-
9	Corn	Insect-resistant (IR-III)[d]	2	0.5	-
10	Cotton	Insect-resistant (IR-IV)[e]	51	46	42
11	Cotton	Insect-resistant (IR-V)[f]	1	0.2	-

[a] Adoption in GA, FL, MI, NJ, NC, SC, TN as a percent of total US planted acreage in 2004; Adoption in GA and FL as a percent of total US planted acreage in 2003; Adoption in GA and FL as a percent of total planted acreage in these two states in 2001.

[b] European corn borer/southwestern corn borer/corn earworm-resistant corn (includes YieldGard Corn Borer and Herculex I).

[c] European corn borer/southwestern corn borer/black cutworm/fall armyworm/corn earworm-resistant corn (Herculex I).

[d] Rootworm-resistant corn (YieldGard Rootworm).

[e] Bollworm and budworm-resistant cotton (Bollgard).

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

Results

The widespread and increased adoption of biotechnology-derived crops in 2004 is a testimony to the growers' confidence in these crops and also to the positive impacts they generated thus far. Biotechnology-derived crops improved crop yields, reduced reliance on pesticides, reduced farm production costs, and enhanced the bottom-line to growers in 2004, similar to years before (Table 3).

Yield impacts in 2004, similar to other years, have been greatest for insect-resistant crops, due to season-long protection from key pest problems. Economic impacts, on the other hand, have been greatest from herbicide-resistant crops. Herbicide-resistant crops provided effective weed control with fewer herbicides and fewer applications. Costs associated with tillage and handweeding were reduced in crops such as cotton. All these impacts were translated to reduced production costs and significant grower cost savings. Furthermore, pesticide use in 2004 was 62.0 million pounds lower than it would have been without the use of biotechnology-derived crops.

Table 3	**Impact of biotechnology-derived crops planted in 2004**							
Case Study	**Crop**	**Trait[1]**	**Production**			**Total net value**	**Reduction in pesticide use**	**Acreage[2]**
			Volume Million lbs.	**Value** Million $	**Cost**s Million $	Million $	Million lbs. ai[3]	Million acres
1	Papaya	VR	11.8	4.37	0.06	4.31	0	0.001
2	Squash	VR	64.4	20.2	0.95	19.2	0	0.006
3	Canola	HR	0	0	-7.9	7.9	0.42	0.585
6	Soybean	HR	0	0	-1,371	1,371	22.4	64.0
7	Corn	IR - I	4944.7	216.3	60.0	156.4	3.83	22.35
8	Corn	IR - II	636.0	28.0	-12.4	40.4	0.28	1.46
9	Corn	IR - III	363.7	16.0	2.6	13.4	0.67	1.32
4	Corn	HR	0	0	-138.7	138.7	18.49	16.70
10	Cotton	IR – IV	561.9	337.1	53.62	283.5	1.61	6.94
11	Cotton	IR - V	24.9	14.9	1.19	13.7	0.15	0.195
5	Cotton	HR	0	0	-263.9	263.9	14.14	10.77
Total			**6,607**	**637**	**-1,675**	**2,312**	**61.99**	

[1]Trait: VR, virus-resistance; HR, herbicide-resistance; IR, insect-resistance.
[2]Acreage is not totaled because, in some cases, cultivars with multiple traits could be planted on the same acre.
[3]ai refers to active ingredients.

Impacts by trait

Of the three traits that are in commercial production in the United States, biotechnology-derived insect-resistant crops had the greatest impact, by far, on crop yields. Of the 6.61 billion pounds of gained production in 2004, insect-resistant or Bt crops accounted for 6.5 billion pounds or 99%. Gained production from Bt crops was valued at $612 million in 2004.

Herbicide-resistant crops led to greatest reduction in crop production costs and greatest increase in net economic impacts. Herbicide-resistant crops reduced production costs by $1.8 billion dollars in 2004, which was 17% further reduction compared with 2003. Reduction in crop production costs due to herbicide-resistant soybean alone was $1.4 billion. Herbicide-resistant crops have also contributed to significant reductions in pesticide use. For example, herbicide-resistant crops reduced pesticide use by 55.5 million pounds while insect-resistant crops accounted for 6.5 million pounds. Pesticide use was reduced further in 2004, compared with 2003, due to the increased acreage of Liberty Link crops such as canola, corn, and cotton. Glufosinate (Liberty) is used at lower rates than glyphosate (Roundup) and thus higher pesticide use reduction in 2004. Though pesticide use has remained unchanged with the virus-resistant crops, significant production gains have been noted with these crops (76 million pounds).

Table 4	**Impact of biotechnology-derived crops by pest management trait in 2004**				
Trait	**Production**			**Total net value**	**Reduction in pesticide use**
	Volume Million lbs.	**Value** Million $	**Costs** Million $	Million $	Million lbs. ai[1]
Herbicide-resistance	0	0	-1,781.5	1,781.5	55.45
Insect-resistance	6,531.2	612.3	105	507.4	6.54
Virus-resistance	76.2	24.57	1.01	23.51	0
Total	**6,607**	**637**	**-1,675**	**2,312**	**61.99**

[1]ai refers to active ingredients.

Impacts by crop

Significant crop production gains were obtained with insect-resistant and virus-resistant crops. Crop yields were not affected by herbicide-resistant crops as weed control offered by herbicides associated with these crops was similar to that provided by herbicides used in conventional crops. While biotechnology-derived field corn accounted for 90% of the 6.6 billion pounds of production increase due to biotechnology-derived crops, Bt cotton and virus-resistant crops (papaya and squash together) contributed to 9 and 1% of the production gain, respectively.

Across all six crops studied, planting of biotechnology-derived soybean resulted in largest net returns to growers at $1.4 billion dollars followed by cotton ($561 million) and corn ($349 million). The impacts of papaya, squash, and canola were small compared

to soybean, corn, and cotton, mainly due to their minor acreage. When combined, the net economic impact of papaya, squash, and canola was 1.4% of the total. Reduction in pesticide use, on the other hand, was greatest in corn (23 million pounds) followed by soybean (22 million pounds), and cotton (16 million pounds).

Table 5	**Impact of agricultural biotechnology by crop in 2004**						
#	**Crop**	**Production**			**Total net value**	**Reduction in pesticide use**	**Acreage**
		Volume Million lbs.	**Value** Million $	**Costs** Million $	Million $	Million lbs. ai	Million acres
1	Papaya	11.8	4.37	0.06	4.31	0	0.001
2	Squash	64.4	20.2	0.95	19.2	0	0.006
3	Canola	0	0	-7.9	7.9	0.42	0.585
4	Soybean	0	0	-1,371	1,371	22.4	64.0
5	Corn	5,944.4	260.3	-88.5	348.9	23.27	41.83
6	Cotton	586.8	352	-209.1	561.1	15.9	17.90
Total		**6,607**	**637**	**-1,675**	**2,312**	**61.99**	

[1]ai refers to active ingredients.

Impacts by state

As depicted in Table 6, the 43 states that planted biotechnology-derived crops in 2004 realized significant benefits. The midwestern states experienced the greatest impacts in all categories in 2004, similar to 2003. While gain in crop production was greatest in Nebraska (1.13 billion pounds) followed by Iowa (1.11 billion pounds) and Minnesota (0.73 billion pounds); reduction in crop production costs was highest in Iowa ($218 million), followed by Indiana ($195 million), and Illinois ($191 million). Net grower returns were highest in Iowa followed by Illinois and Minnesota in 2004. Reduction in pesticide use due to biotechnology-derived crops was greatest in Iowa (9.1 million pounds) followed by Minnesota (8.1 million pounds) and Illinois (7.4 million pounds).

Aggregate impacts

The planting of six biotechnology-derived crops in 2004 has led to gained production of 6.6 billion pounds, reduced production costs of $1.7 billion, and increased revenue of $2.3 billion. In comparison to 2003, production increase was 24% higher, production costs were 13% lower, and economic returns were 21% greater. Furthermore, American growers used 62 million fewer pounds of pesticides in 2004 due to the adoption of biotechnology-derived crops.

Table 6	Total impact of biotechnology-derived crops by state in 2004				
State	**Production**			**Total net value**	**Reduction in Pesticide use**
	Volume 000 lbs.	**Value** 000 $	**Costs** 000 $	000 $	000 lbs. ai[1]
Alabama	33,495	20,097	-13,321	31,220	668
Arkansas	95,811	41,974	-96,469	144,075	3,595
Arizona	18,705	8,295	-3,662	13,822	383
California	10,672	2,496	-7,429	31,552	1,060
Colorado	135,062	5,913	-4,532	10,505	756
Delaware	13,684	598	-5,732	6,330	216
Florida	36,123	14,020	183	13,352	202
Georgia	110,503	58,344	-36,016	88,933	3,353
Hawaii	11,820	4,373	57	4,316	0
Idaho	2,021	89	-624	713	84
Illinois	601,993	26,361	-190,704	217,065	7,414
Indiana	88,709	3,889	-195,242	199,131	7,006
Iowa	1,110,212	48,631	-217,522	266,153	9,130
Kansas	456,609	20,803	-53,983	74,832	2,532
Kentucky	27,944	1,222	-11,530	12,752	-457
Louisiana	58,612	23,298	-36,973	59,275	2,024
Maryland	64,710	2,830	-6,986	9,816	458
Massachusetts	0	0	-25	25	3
Michigan	83,087	3,864	-32,563	36,427	-10
Minnesota	728,077	31,906	-180,746	212,652	8,123
Mississippi	79,338	46,075	-39,538	82,126	3,234
Missouri	340,915	29,848	-117,511	147,112	5,285
Montana	2,576	113	53	60	1
North Carolina	57,309	29,436	-31,087	64,214	1,427
North Dakota	168,752	7,383	-53,344	60,727	-923
Nebraska	1,127,586	49,387	-47,334	96,721	3,909
New Jersey	13,756	2,721	-1,339	4,060	87
New Mexico	8,344	2,273	215	2,043	78
New York	9,464	414	-4,857	5,271	354
Ohio	43,771	1,919	-30,561	32,480	-4,236
Oklahoma	27,845	7,526	-5,949	11,997	368
Pennsylvania	54,494	2,388	-5,705	8,093	522
South Carolina	18,974	10,712	-11,163	23,357	180
South Dakota	442,889	19,382	-68,645	88,027	545
Tennessee	85,988	28,194	-34,841	61,263	1,223
Texas	292,836	70,662	-100,638	149,206	2,678
Utah	0	0	-235	235	30
Virginia	18,855	4,025	-5,939	10,076	430
Vermont	2,016	88	-64	152	15
Washington	1,232	53	25	28	1
West Virginia	0	0	-398	398	29
Wisconsin	122,579	5,365	-26,394	31,759	143
Wyoming	0	0	-227	227	29

[1] ai refers to active ingredients.

Biotechnology-derived crops and no-tillage

The adoption of biotechnology-derived crops has led to significant positive environmental impacts in addition to agronomic and economic benefits. Conservation tillage practices, no-till in particular, have increased significantly since the adoption of biotechnology-derived herbicide-resistant crops. Grower surveys and expert polls strongly indicate that the adoption of herbicide-resistant crops correlated positively with the increase in no-till acreage since 1996, the year when herbicide-resistant crops were first planted on a commercial scale.

Weed control is a major concern in no-till fields when poor weather conditions hamper the effectiveness of herbicides. Herbicide-resistant crops increased growers' confidence in their ability to control weeds without relying on tillage because herbicides used in biotechnology-derived crops are more effective than those used before. With that increased confidence, American growers planted 64, 20, and 371% more acres to no-till in soybean, corn, and cotton, respectively, in 2004, compared with years before their introduction.

The Conservation Technology Information Center (CTIC) reported in 2002 that increased use of conservation tillage practices such as no-tillage reduced soil erosion by nearly 1 billion tons and saved $3.5 billion in sedimentation treatment costs. Other benefits from no-tillage included significant fuel savings (3.9 gallons of fuel per acre), reduced machinery wear and tear, reduced pesticide (70%) and water runoff (69%), reduced greenhouse gases due to improved carbon sequestration, and improved habitat for birds and animals. Some experts have credited herbicide-resistant crops for transforming American agriculture from a carbon intensive operation to a potential carbon sink. By providing more assured weed control, biotechnology-derived herbicide-resistant crops facilitated the increase in no-till production practices and the associated environmental and economic benefits.

Conclusion

American experience from the ninth year of planting biotechnology-derived crops indicate that these crops have provided reliable and flexible alternatives to traditional pest management choices, reduced the total amount of input costs in farming, and improved crop yields, all of which have translated to direct economic benefits to farmers. The numeric value of the benefits reaped from 118 million acres of crop land planted to biotechnology-derived crops in 2004 was improved grower net returns of $2.3 billion.