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

Executive Summary

February 2008

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Table of Contents

Key Findings

This report updates the 2005 publication entitled "Biotechnology-Derived Crops Planted in 2005 - Impacts on US Agriculture" and confirms that the trends toward adoption, reduction in chemical active ingredients applied and economic benefits to farmers continued in 2006. Biotechnology-derived crops have, in fact, started their second decade of being planted in the US and have resulted in even greater impacts for US agriculture in 2006. The report that is the subject of this summary, evaluated in detail the reasons for the increases in plantings of biotechnology-derived crops in terms of incentives to farmers using essentially two criterions: economic benefits related to cultivation and improved yields; and reductions in active chemical ingredients applied to the acres in biotechnology-derived crops.

US growers planted eight biotechnology-derived crops in 2006 - alfalfa, canola, corn, cotton, papaya, soybean, squash and sweet corn. Planted acreage was mainly concentrated in 13 different applications - herbicide-resistant alfalfa, canola, corn, cotton, and soybean; virus-resistant squash and papaya; three applications of insect-resistant corn; two applications of insect-resistant cotton; and insect-resistant sweet corn. Planted acreage of biotechnology-derived varieties expanded for most crops in 2006, and economic benefits were increased by both the increased acres and generally higher crop prices, which made the increased yields worth more.

Production and Economic Impacts

The planted biotechnology-derived crops in 2006 led to improved crop production of 7.778 billion pounds, lower crop production costs of approximately $1.9314 billion and reduced pesticide use of 110.06 million pounds (Table 1). Increased revenue from higher yields and reduced production costs improved net returns to growers by $2.629 billion. The major differences between 2005 and 2006 were due to higher crop prices and increased adoption of insect-resistant corn and cotton cultivars, which had large impacts on yields. As mentioned, there were higher crop prices in 2006 than in 2005.

Compared to 2005, planted acreage in biotechnology-derived crops increased from 123 million to 156 million acres or 12.7 percent. Yield increases were down from 8.3 billion pounds to 7.7 billion pounds or 10.7 percent. However, the net economic impact was up from $2.0 billion to $2.6 billion or 13 percent. Again, the rather large increases were due to increased adoption of insect-resistant varieties. In addition, the increases in adoptions and yield came from a different source in 2006. Comparisons of 2005 and 2006 are confounded by several factors including differences in relative prices of chemicals and biotechnology-derived cultivars to output prices. The year 2006 saw major price increases. For example, the USDA reported the annual price of corn moved from about $2 per bushel in 2005 to $3 a bushel during 2006. Other prices moved similarly during the year. As well, this was the year that the "stacked" traits in crop cultivars were first merchandized to any degree.

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
2006	156	7.78	1.9	2.6	110.1
2005	123	8.34	1.4	2.0	69.7
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]ai refers to active ingredients.
Also refer to the Appendix for
additional documentation.

Pesticide Use Impacts

The herbicide-resistant crops again accounted for 91 percent, which is the major share of pesticide use reduction in 2006. Insect-resistant corn accounted for most of the rest of the reduction in pesticide use. Herbicide-resistant accounted for the major share of 47 percent, followed by cotton and soybean which were closely tied at 24.5 and 23.1 million pounds or 22.2 and 21.0 percent, respectively. The insect-resistant crops accounted for 8.6 percent of the reduction in pesticide applications. One of the unquantifiable effects of the insect-resistant crops was the "halo" effect, which holds that the insect populations are affected by the use of insect-resistant crops. This means less spraying for the non biotechnology-derived crops and that farmers who do not use the biotechnology-derived crops benefit from the use of biotechnology-derived crops by other growers.

Crop Impacts

Biotechnology-derived insect-resistant corn and cotton and virus resistant papaya and squash led to significant gains in crop production in 2006, similar to prior years. Yield improvements were not noted for any of the herbicide-resistant crops because weed management efficiency for the non-resistant crops was assumed to take care of the pests. This assumption is likely not completely true and there is a yield impact for herbicide-resistant crops, as well. Except for the virus-resistant crops, all other crops contributed to reduced pesticide use in 2006.

Biotechnology-derived varieties improved corn production by 6.92 billion pounds in 2006, down from the estimated 7.6 billion pounds in 2005. The insect-resistant cotton varieties increased production by .77 billion pounds. Soybean herbicide-resistant varieties reduced production costs by $1.56 billion. Herbicide-resistant corn was next in level of production costs, reduced at $.32 billion. Other crops accounted for smaller amounts of reduced costs, which in total were $1.93 billion. To put these numbers in perspective, net farm income for US agriculture was $69.8 billion in 2007 as shown in the latest FAPRI statistics (www.fapri.missouri.edu).

State Impacts

All states in which biotechnology-derived crops were planted had benefits from the use of these varieties. Hawaii and Ohio were the only states in which the use of biotechnology-derived crops did not result in reductions in pesticide use. The states with significant economic benefits were Iowa, Minnesota and Illinois. States that had increased benefits included Arkansas, Kansas, Missouri, Nebraska, North Carolina, North Dakota, Ohio and South Dakota, which are primarily the states in the Corn Belt of the US.

Pesticide use decreased the most in Iowa, not Minnesota, as in 2005. States in which pesticide use was reduced by more than 1 million pounds were Alabama, Arkansas, Colorado, Georgia, Illinois, Indiana, Iowa, Kansas, Louisiana, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New York, Ohio, Pennsylvania, South Dakota, Tennessee, Texas, and Wisconsin. This shows that although the economic benefits and pesticide use reductions are concentrated in the Corn Belt, there is a wide distribution of the benefits across the US.

Cost reductions were generally the largest in the states that had the highest net value of benefits. Those with the largest reductions were Illinois, Iowa and Minnesota. The largest reduction was in Illinois. States with more that $100 million of reductions in cost included Illinois, Indiana, Iowa, Minnesota, Missouri, and South Dakota.

Study Background and Purpose

American growers planted biotechnology-derived crops on 156 million acres in 2006. This was the beginning of the second decade of growing biotechnology-derived crops in the US, and saw a continued increase in planted acres. It was also a year when traits of biotechnology-derived crops were first widely marketed as "stacked". This is a trend that will likely continue and become more common in the future, and includes cultivars for both herbicide-resistant crops and for insect-resistant crops. American growers are expressing increased confidence in biotechnology-derived crops as indicated by the growing acreage planted and the adoption of combined or stacked technologies.

In fact, the technology-derived crops planted represented major portions of the total acreage in the US. For example, the total planted acreage for corn in 2007 was 93.6 million acres and corn planted to herbicide-resistant in 2006 was 41 million acres - nearly half of the total acres planted. Cotton planted to herbicide-resistant varieties was 13.2 million acres in 2007 and the total base acres in 2006 were 18.4 million. The planted acres of soybean were 63.6 million acres in 2007 and the soybean planted to herbicide-resistant varieties was 67.8 million acres in 2006. (Corn acreage increased and soybean acreage decreased, due to relative prices). These projected total planted acreage figures are from the Food and Agricultural Policy Research Institutes March 2008 US Baseline Briefing Book (www.fapri.missouri.edu).

Study Context

Four earlier reports from the National Center for Food and Agricultural Policy entitled "Plant Biotechnology: Current and Potential Impact for Improving Pest Management in US Agriculture," in 2002, "Impact on US Agriculture of Biotechnology-derived crops planted in 2003," Biotechnology-Derived Crops Planted in 2004," "Biotechnology-Derived Crops Planted in 2004—Impacts for US Agriculture" and "Quantification of the Impacts on US Agriculture of Biotechnology-Derived Crops Planted in 2005," documents a clear upward trend in the adoption of biotechnology-derived crops in the US. In fact, new information presented in this report suggests that in the case of herbicide-resistant crops the biotechnology-derived crops have reached almost 50 percent of the total planted acreage in the US.

Since the last study the acreage of crops planted to biotechnology-derived crops has increased from 123 to 156 million acres, or 33 million acres. Major improvements in biotechnology-derived crops have made the stacked traits, and with making the application of insecticides more available up to nearly the harvesting date as opposed to earlier restrictions on applications. In short, the biotechnology-derived crops have become more "grower friendly" in the sense of reduced limitations on application of herbicides and pesticides, and the availability of stacked traits that are even more important to growing crops and controlling pests.

Methods and Cases

The methods of calculating the impacts or benefits of biotechnology-derived crops were straight forward and consistent with the previous studies mentioned above. Changes in production volume were measured based on yield changes that have occurred when biotechnology-derived crops have replaced conventional crops. Changes in production value were calculated based on yield changes and crop prices. Changes in production costs were calculated by determining which of the current cultivation practices would have been affected by the use of crops that are biotechnology-derived.

Adoption costs associated with the use of technology, either as a technology or a royalty fee or seed premium, were considered in the calculations. Finally, changes in pesticide use were quantified when the biotechnology-derived crop cultivar replaced or was substituted for the current use of the pesticides, leading to either an increased or reduced usage. The impacts were calculated using 2006 crop production data for which the US Department of Agriculture, National Agricultural Statistics Service, was the major source of information.

University researchers and university extension crop specialists were surveyed to obtain first hand information on the existing pest management practices on conventional crops and to assist in determining how biotechnology-derived crops replaced or substituted for current practices. In addition, we used the Doane 2006 Corn TraitTrack Data for this year to get a better handle on the corn insecticide-resistant cultivar use. Another source in addition to the interviews with crop scientists and extension crop specialists was Williams cotton insect losses www.missstate.ed/Entomology/resources/cotton/cotton.html.Updated in which estimations were sent to reviewers for comment and evaluation. The report contains results for the 10 case studies. The full report containing all 10 case studies can be accessed at www.ncfap.org/.

Adoption of Biotechnology-Derived Crops in 2006

Information on the biotechnology-derived crops planted is presented in Table 2 for 2006. As reported in the past studies, herbicide-resistant crops were planted on a large share of the total acreage. The rapid spread of the adoption of the herbicide-resistant crops is mainly due to the enhanced flexibility and simplicity of weed management for these crops. The adoption of insect/virus resistant crops in contrast is related to anticipated levels of targeted pest infestation and may vary from year to year. Adoption of these cultivars will continue to increase in the future as the industry develops more adapted cultivars to different regions of the nation and the crop prices are higher, as is expected, making risk of loss of yields more costly to growers.

Looking specifically at the results in Table 2, note that virus resistant papaya and herbicide-resistant soybean had the highest adoption rate at 90 percent. Herbicide-resistant corn increased in adoption appreciably in 2006 over 2005. In the case of insect-resistant corps, there was more of a mixed bag. In the case of corn, the differences between IR-I and IR-II almost cancelled out to make the total adoption rate about the same as in 2005. For cotton, there was an increase in the combined IR-III and IR-IV cultivars. In both cases the adoption of the IR-II and IR-IV varieties was due to increased farmer friendly aspects of the traits. As well, this is a place where the major source of data was somewhat different than in 2005

Table 2. Adoption of biotechnology-derived crops in the United States.

Case study	Crop	Trait	Percentage adoption				
			2006	2005	2004	2003	2001
1	Papaya	Virus-resistant	90	55	56	46	37
2	Squash	Virus-resistant	13	12	10	3	17
3	Canola	Herbicide-resistant	87	93	75	75	70
4	Corn	Herbicide-resistant	53	35	18	14	8
5	Cotton	Herbicide-resistant	86	80	77	74	59

6	Soybean	Herbicide-resistant	90	88	85	82	69
7	Corn	Insect-resistant (IR-I)[a]	21	34	28	30	21
8	Corn	Insect-resistant (IR-II)[b]	10	4	2	0.5	–
9	Cotton	Insect-resistant (IR-III)[c]	49	55	21	46	42
10	Cotton	Insect-resistant (IR-IV)[d]	15	2	1	0.2	–

[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).

Results

Estimates of benefits that were realized by growers in the form of enhanced crop yields, improved insurance against pest problems, reduced pest management costs, decreased pesticide use and overall increased grower returns are presented in Table 3. While again the control of key pests that resulted in increased yields and reduced insecticide use were the main reasons for the success of biotechnology-derived crops, simplicity and flexibility of weed management afforded by the herbicide-resistant crops enhanced their adoption. Simply put, weeds are a problem everywhere insect infestations are more spotted in terms of incidence.

Similar to the 2005, in 10 crop case studies, the herbicide-resistant crops had the largest economic impacts. But, the insect-resistant crops had appreciable impacts because of increased use of the biotechnology-derived cultivars and because of increased prices of crops. Implications for the future are that crop prices will stay high as is indicated by the FAPRI projections. If this is the case, the implication is for greater use of yield increasing biotechnology-derived crops, perhaps even changing the balance of use between the herbicide and insecticide-resistant cultivars.

Table 3. Impact of biotechnology-derived crops planted in 2006.

Case Study	Crop	Trait[1]	Production			Total net value	Reduction in pesticide use	Acreage[2]
			Volume	Value	Costs			
			Million lbs.	Million $	Million $	Million $	Million lbs. ai[3]	Million acres
1	Papaya	VR	5.2	2.0	0.2	1.8	0	0.002
2	Squash	VR	78.4	25.4	1.2	24.2	0	0.008
3	Canola	HR	0	0	-9.5	9.5	0.6	0.95

4	Corn	HR	0	0	-315.5	315.5	52.3	41.02
5	Cotton	HR	0	0	-27.7	27.7	24.5	13.20
6	Soybean	HR	0	0	-1,561.6	1561.6	23.1	67.74
7	Corn	IR - I	3645.8	196.0	10.4	185.6	2.9	16.60
8	Corn	IR - II	3274.7	176.8	-7.7	184.5	3.9	7.69
9	Cotton	IR - III	604.6	260.0	17.5	242.5	1.9	7.46
10	Cotton	IR - IV	171.2	73.6	0.6	73.0	0.9	1.34
Total			**7,779.9**	**733.8**	**-1,892.1**	**2,625.9**	**110.1**	

[1]VR: virus-resistant, HR: herbicide-resistant IR: insect-resistant.
[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.

Impact by Trait

2006 had a different story than 2005 in terms of impacts of biotechnology-derived crops by pest management trait. Total volume in millions of pounds of production was down from 8,341 to 7,779.9. But, the value of production was up from $578 million in 2005 to $733.8 million in 2006, primarily due to higher farmer crop prices. Costs were higher than 2006, due to higher prices for seeds related to increased crop prices. Total net value of was up from 2,017 million dollars in 2005 to 2,625.9 million dollars in 2006. Reduced pesticide use was greater than in 2005 by about 20 million pounds of active ingredients. In some cases this was due to the increased flexibility permitted for herbicide use.

Table 4. Impact of biotechnology-derived crops by pest management trait in 2006.

Trait	**Production**			**Total net value**	**Reduction in pesticide use**
	Volume	**Value**	**Costs**		
	Million lbs.	Million $	Million $	Million $	Million lbs.ai[1]
Herbicide-resistance	0	0	-1914.3	1914.3	100.5
Insect-resistance	7696.3	706.4	20.8	685.6	9.6
Virus- resistance	83.6	27.4	1.4	26.0	0.01
Total	**7779.9**	**733.8**	**-1892.1**	**2625.9**	**110.1**

[1]ai refers to active ingredients.

Impacts by Crop

Examining the impacts by crop is of interest relative to the geography of the impacts as well as the figures on impacts themselves. Biotechnology-derived soybean accounted for 83 percent of the production costs in 2006, compared to 91 percent of the costs in 2005. Total net value was again distributed among soybean, corn and cotton, largely related to total acreage and percent of adoption. Reductions in pesticide use were greatest for corn, which accounted for about 53 percent of the total of 110.1 million pounds. Acreage was similar in proportion between corn and soybean at about 65 percent.

Table 5. Impact of agricultural biotechnology by crop in 2006.

Crop	Production			Total net value	Reduction in pesticide use	Acreage
	Volume	Value	Costs			
	Million lbs.	Million $	Million $	Million $	Million lbs.ai[1]	Million acres
Papaya	5.2	2.0	0.2	1.8	0	0.002
Squash	78.4	25.4	1.2	24.2	0	0.008
Canola	0	0	-9.5	9.5	0.6	0.95
Soybean	0	0	-1,561.6	1561.6	23.1	67.74
Corn	6920.5	372.8	-312.8	685.6	59.1	65.31
Cotton	775.8	333.6	-9.6	343.2	27.3	22.00
Total	**7779.9**	**733.8**	**-1892.1**	**2625.9**	**110.1**	

[1]ai refers to active ingredients.

Impacts by State

The state by state impacts are provided in Table 6. Generally, the impacts are related to the acreages of crops by state. Illinois had the highest net value over Iowa as in 2005. However, pesticide reductions were greater in Iowa than in Illinois. It is interesting to make ratios of the value related to the reduction of pesticide use. These ratios point out that some of the "fringe "areas to the Corn Belt may have greater problems with pests or more limited times for cultivation of common variety crops, resulting in greater savings in pesticide use.

Table 6. Aggregate impacts of biotechnology-derived crops by state in 2006.

State	Production			Total net value	Reduction in pesticide use
	Volume	Value	Costs		
	000 lbs.	000 $	000 $	000 $	000 lbs. ai[1]
Alabama	41,138	17,689	1,017	16,403	1,115
Arizona	19,087	8,190	2,121	6,086	266
Arkansas	102,648	38,428	-77,353	115,781	4,256
California	6,010	2,584	-25,952	28,536	582

Colorado	141,233	7,610	-5,826	13,436	1,044
Delaware	11,640	626	-6,628	7,254	250
Florida	27,590	10,844	3,385	7,458	232
Georgia	161,955	56,659	4,121	52,537	4,314
Hawaii	5,224	1,951	200	1,800	0
Idaho	4,312	230	-1,239	1,469	198
Illinois	1,290,242	69,574	-256,368	325,942	12,501
Indiana	295,276	15,928	-160,422	176,350	9,781
Iowa	1,167,899	62,944	-237,936	300,880	14,306
Kansas	439,486	24,285	-74,697	98,984	4,445
Kentucky	9,072	487	-12,038	12,525	31
Louisiana	55,221	21,744	-27,664	49,408	2,489
Massachusetts	0	0	-97	97	16
Maryland	49,952	2,684	-8,820	11,504	526
Michigan	106,454	6,013	-51,164	57,177	2,455
Minnesota	1,049,832	56,559	-241,320	297,879	12,560
Mississippi	116,421	40,337	-36,686	77,013	5,072
Missouri	128,750	21,694	-113,305	134,999	3,678
Nebraska	683,813	36,810	-99,497	136,307	8,068
New Jersey	1,800	5,320	-2,939	8,259	118
New Mexico	9,417	2,743	1,280	1,464	115
New York	77,690	4,189	-9,231	13,420	965
North Carolina	86,605	30,542	-51,503	82,045	3,559
North Dakota	160,353	8,619	-86,848	95,467	205
Ohio	120,158	6,480	-94,672	101,553	-3,287
Oklahoma	75,746	16,284	-2,731	19,014	855
Pennsylvania	49,530	2,670	-14,913	17,583	1,331
South Carolina	27,546	11,293	-10,524	21,817	776
South Dakota	554,351	29,833	-111,264	141,096	6,912
Tennessee	65,413	25,155	-44,130	69,285	1,962
Texas	382,015	71,121	11,273	59,848	9,235
Utah	0	0	-427	427	68
Virginia	16,432	2,677	-5,940	8,619	986
Vermont	0	0	-204	204	33
West Virginia	0	0	-336	336	46
Wisconsin	239,409	12,904	-42,678	55,583	1,841
Wyoming	0	0	-622	622	98

[1]ai refers to active ingredients.

Aggregate Impacts

Compared to 2005, biotechnology-derived crops resulted in slight decreases in production of volume, 777.9 million pounds in 2006 related to 8,341 for 2005. The value of production increased as already mentioned, largely due to crop prices.

Pesticides were reduced by a greater amount in 2006 compared to 2005, 40 million pounds of ai. This was due to the greater regional adaptation of cultivars and the fact that the common varieties were apparently more susceptible to weeds during the 2006 crop season. This information came to us from the research crop and extension crop specialists. The net value of the adoption of biotechnology-derived crops was, however, up for 2006 compared to 2005, 2,625.9 compared to 2,017, respectively.

Biotechnology-derived crops and no-till

The last national study of no-till cultivation was in 2004. For this reason many of the research crop specialists and extension crop specialists were asked about the impact of biotechnology-derived crops on no-till increases. The answer was mixed, largely because what is no-till and what is limited-tillage has become less clear. There is decidedly a trend to limited and no-till cultivation—largely related to costs of cultivation. It is clear that the biotechnology-derived crops add to this trend by reducing the cost of weed control. But is not clear where the burden of the cost reduction lies—it is likely related to both with the biotechnology-derived crops as a necessary condition for the switch to limited and no-till cultivation.

Biotechnology and Bio-fuels

The 2005 summary report had quite a long discussion about the possible impacts of bio-fuel production and use on the use of biotechnology-derived varieties. With a year's time, there is even more to say about bio-fuels and corn production. A major change is in the implications for bio-fuel production with the Energy Independence Security Act of December 2007 (EISA) mandates. FAPRI figures show bio-fuel increasing in production and mostly at the cost of corn that could be used for other purposes. Government subsidies play an important role in bio-fuel production and have changed with the EISA mandates. Our assumption is that the EISA mandate will be removed. This will cause the corn-based ethanol to increase in price and corn-based production of ethanol to increase.

If the EISA mandate is waved, ethanol production will hover around 13 to 14 billion gallons, or between 3 and 4 bushels of corn, in the immediate out years. Further increases in ethanol will require a breakthrough in technology, causing cellulosic ethanol production to become more profitable or less loss making. The situation here is very unpredictable. The technology will come but at what date is the uncertainty. The result is that corn based ethanol continues to increase in production but at a much slower pace that in the past years. And, imports of ethanol are a particular possibility if the US is to meet the mandates set out by the current administration. The FAPRI projections show imports to sharply increase, mainly from Brazil, during the last five years of their 10 year projections.

The impact will be increased use of cultivars that improve yields and stacked cultivars that improve yield and reduce the incidence of weed and insect pests. The production systems for corn encourage use of herbicide-resistant varieties due to the larger farms that are ever increasing in size and the flexibility of weed control. In addition, the insect-resistant varieties will increase in popularity due to the higher price of corn, as the yield is worth more. The "halo" effect may counter these trends, since when there are no varieties for the insects to consume, the insect populations may be reduced. At the fringe is the conservation reserve land that will be brought back into production. First time uses of this land will likely not require the use of biotechnology-derived insect-resistant cultivars, since many of the insects, corn root worm for example, are most prevalent in continuous or near continuous corm production.

In the longer run, cellulosic production of ethanol will become more feasible. Current estimates are that the cellulosic production of ethanol will increase yields of ethanol about 4 to 5 times per acre. This will set into motion a different dynamic relative to ethanol production and competition for food grain. Simply put, the competition will be decreased. This reduction in competition will, however, be countered by the increased demand for food worldwide. It is important to realize that prices of corn would be higher than several years ago even without the ethanol production increase, because the world wide demand for feed and food grains is increasing rapidly.

Changing the Calculations

In the current report we stayed with the approach to calculating the benefits of biotechnology-derived crops that had been used in the past. This was because we wanted to make our results consistent with the previous studies. But there is clearly room for improvement. The major area in which the calculations could be improved is by explicitly including impacts of biotechnology-derived crops on risk. Among other things this would switch the cost of seed or premium for the biotechnology-derived crop to the other side of the ledger. Growers do not have to buy the biotechnology-derived varieties. They do so because the benefit of planting them exceeds the "cost". This means that the risk improvement is at least worth the cost of the biotechnology-derived varieties. Thus, by taking this approach we would get a much higher benefit from the biotechnology-derived varieties. The cost of the biotechnology-derived varieties is thus a benefit of their availability, not a cost. We feel that these are the types of calculations that in the future should be made in evaluating the biotechnology-derived crops.

New Developments

Several new developments have occurred during this year 2006. The stacked traits have been more actively marketed and have become more adapted to different regions of the US. The implication is for a more careful investigation of the impacts of these herbicide and insect-resistant cultivars. We have at several points in this summary indicated that the calculations of benefits should be reviewed, especially relative to risk adverse farmers and lenders. The purely accounting approach to calculating benefits of biotechnology-derived crops grossly under-estimates their value to the growers and to society at large. More economic methods of estimation would generate greater benefits and be more reflective of the true value of biotechnology-derived crops. We recommend a study to determine an improved way of estimating the benefits of biotechnology-derived crops. It would use some of the same methods of gathering data that have been used in past reports, but very different approaches to calculation of benefits.

Conclusions

Crops management decisions have consequences in terms of benefits and costs to growers. Decisions about biotechnology-derived crops in production systems are no exception. In the US, biotechnology-derived crops have had a major impact on production practices and on yield. First, the herbicide-resistant crops had little effect on production, but a greater effect on production costs, flexibility and chemical use. Their impact in this report is assumed to be zero for yields, which is questionable. The impact of herbicide-resistant crops was in cultivation costs and practices. The cost of cultivation estimates showed that the use of herbicide-resistant crop varieties reduced costs significantly. Second, the insect-resistant varieties for corn borer, corn root worm and cotton boll worm had an effect on the yield as well as the cultivation practices and insecticide use. Third will or have come the stacked traits, which we feel will become more commonplace in future years. Growers are now accustomed to using biotechnology-derived crops and will increasingly adopt the stacked traits cultivars as general insurance that yields and cultivation costs will not be affected by pests. Fourth will be other improvements in varieties that will address dietary and other issues related to consumption. These promise to generate even more valuable benefits of biotechnology-derived crops directly to both consumers and producers.

APPENDIX

Crop	Planted acreage	Yield increase	Reduction in production costs	Net economic impact	Pesticide use reduction
	Million acres	Billion pounds	Billion dollars	Billion dollars	Million pounds
VR Papaya	0.002	0.005	-0.0002	0.002	*
VR Squash	0.008	0.078	-0.001	0.024	*
HR Canola	0.952	*	0.010	0.01	0.60
HR Corn	41.02	*	0.316	0.316	52.30
HR Cotton	13.195	*	0.028	0.028	24.50
HR Soybean	67.739	*	1.562	1.562	23.10
IR Corn (Corn Borer)	16.603	3.65	-0.01	0.186	2.87
IR Corn (Rootworm)	7.688	3.27	0.008	0.185	3.92
IR Cotton (Bollgard)	7.464	0.604	0.018	0.243	1.87
IR Cotton (Bollgard II)	1.337	0.171	0.0006	0.073	0.90
TOTAL	**156.008**	**7.778**	**1.9314**	**2.629**	**110.06**

*Data not available.