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Executive Summary

Plant Biotechnology: Current and Potential Impact for Improving Pest Management in U.S. Agriculture

An Analysis of 40 Case Studies

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Leonard P. Gianessi
Cressida S. Silvers
Sujatha Sankula
Janet E. Carpenter

National Center for Food & Agricultural Policy
1616 P Street, NW, Washington, D.C. 20036 Phone: (202) 328-5048 Fax: (202) 328-5133 E-mail: ncfap@ncfap.org
www.ncfap.org

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(For full report, see www.ncfap.org)

Key Findings

The widespread adoption of plant biotechnology (biotech) in major commodity crops in the United States has resulted in significant yield increases, savings for growers and pesticide use reduction. The successful development of additional biotech cultivars for pest management would have similar impact on other crops.

In 2001, eight biotech cultivars adopted by U.S. growers increased crop yields by 4 billion pounds, saved growers $1.2 billion by lowering production costs and reduced pesticide use by 46 million pounds. These cultivars include insect resistant corn and cotton, herbicide tolerant canola, corn, cotton and soybean, and virus resistant papaya and squash. The adopted cultivars provided a net value of $1.5 billion, which was determined by adding any increased value of the crop plus or minus any changes in grower costs.

In addition to these eight, many other biotech cultivars have been or are being developed to control pests. Case-study analyses of 32 such cultivars being developed show that they would increase crop yields by 10 billion pounds per year, reduce growers' costs by $400 million per year and cut pesticide use by 117 million pounds per year. Had these 32 cultivars been adopted, they would have provided a net value of $1 billion.

All together, the impact of the 40 studied cultivars would be increased yields of 14 billion pounds per year, reduced grower costs of $1.6 billion per year and a pesticide use reduction of 163 million pounds per year, compared with existing or previous practices and pest-control products, which would be replaced. (See chart below.) The overall value to U.S. agriculture would be $2.5 billion, based on increased yields and cost savings.

The geographic analysis was limited in scope, so the projected estimates do not represent the total impact that introduction of these biotech cultivars might have. For example, the analysis of insect-protected fresh sweet corn was confined to Florida, the country's leading fresh sweet corn producer. Production in other states was not analyzed or included in the projected impact.

Eight existing cultivars make major impact Among the eight adopted crops, the greatest yield increases came from insect resistant corn (3.5 billion pounds) and insect resistant cotton (185 million pounds). The greatest cost savings was realized in herbicide tolerant soybeans ($1 billion), herbicide tolerant cotton ($133 million) and herbicide tolerant corn ($58 million). The greatest pesticide reduction was seen in herbicide tolerant soybean (28.7 million pounds) and herbicide tolerant cotton (6.2 million pounds).

It is clear that biotechnology, which has largely been utilized by producers of major commodity crops, also has potential to increase yields, lower costs and reduce pesticide use in other crops that are grown on fewer acres. In addition to the eight existing cultivars, many other crops are being transformed and tested to determine their impact on the agricultural economy.

Future products would increase yield, cut pesticide use The greatest predicted yield increase among future products was seen in fungus resistant barley (1.44 billion pounds), herbicide tolerant wheat (1.42 billion pounds), herbicide tolerant sugarcane (1.4 billion pounds) and potatoes resistant to viruses and insects (1 billion pounds). The greatest reduction in current pesticide use could occur in fungus resistant potatoes, which could replace the use of 28 million pounds of soil fumigant and field corn resistant to rootworm, which could replace 14 million pounds of insecticides.

In addition to improving current pest-control practices, biotechnology has the potential to prevent anticipated crop losses from diseases that have devastated crops in other countries and threaten to spread to U.S. crops. The development of virus and bacteria resistant grapes, stone fruit and citrus could protect 2.5 billion pounds of production annually, prevent growers from incurring costs of $161.7 million per year and preclude pesticide use of 60.6 million pounds per year.

Overall Impact of Biotechnology in Pest Management			40 Case Studies
	Yield Increase	Net Economic Impact	Pesticide Reduction
Current Cultivars	4 billion pounds	$1.5 billion	46 million pounds
Potential Cultivars	10 billion pounds	$1 billion	117 million pounds
Total	**14 billion pounds**	**$2.5 billion**	**163 million pounds**

Next wave will emphasize prevention of crop diseases Insect resistance and herbicide tolerance account for the vast majority of currently adopted biotech crops. Nematode control and several disease prevention cultivars (those with bacterial, fungal and viral resistance) will be added to the spectrum of biotech pest-control options as several new cultivars become commercial. This group of cultivars is projected to increase annual yields by about 5.5 billion pounds, reduce grower costs by more than $187 million annually and reduce pesticide use by more than 91 million pounds annually in the states analyzed here.

Every state would see impact of improved pest control Analyses showed that each of the 47 states encompassed by the 40 case studies would realize pest-control improvements. There were no case studies involving Rhode Island, Nevada and Alaska. As might be expected, key agricultural states would realize the most impact from biotech crops. California and North Dakota would see the highest potential economic impact. The greatest production gain (2.41 billion pounds) would be realized in North Dakota, where yield increases would result from fungus resistant barley and herbicide tolerant wheat. Florida would be second, with an expected increase of 1.58 billion pounds due to bacteria resistant citrus and insect protected sweet corn.

California would see the most impact in pesticide reduction (66 million pounds per year) followed by Idaho (18.8 million pounds per year), and Indiana, Iowa, Illinois and Oregon (about 8 million pounds each). Most of the reduction in those states would result from replacing soil fumigants with disease resistant crops and insecticides with insect resistant crops.

Though in Hawaii papaya only grows on 1,600 acres, the development of a virus resistant strain of papaya is credited with saving the Hawaiian papaya industry, which had sustained major yield losses caused by disease.

Introduction

Advances in genetics and molecular biology have made it possible to identify traits in one organism and introduce them into another, regardless of relatedness of the source and recipient species. In the past decade, certain plant species have been modified with genetic material from microorganisms, bacteria, fungi, viruses and unrelated plant species. The resulting transgenic plants express introduced proteins from the donor species. This is commonly referred to as plant biotechnology or agricultural biotechnology.

The first set of widely planted biotechnology crops improves the management of pests (insects, diseases and weeds). These altered plants are immune to disease, kill insects and make it possible to spray nonselective herbicides that kill weeds with no harm to the crop.

The first biotech crops were introduced in 1996, and planting has expanded every year since. In the United States, grower acceptance of biotechnology products in major commodity crops (corn, cotton and soybeans) has been rapid and widespread. U.S. growers have steadily increased their biotech acreage in recent years. In 2001, 66 million acres of herbicide tolerant soybeans, cotton, canola and corn were planted, as were 20 million acres of insect resistant corn and cotton.

Agricultural biotechnology, however, is still in its infancy, with only a few crops impacted by the technology. Researchers are seeking new ways to improve crops by introducing specific genetic material that will express desirable traits. Study is ongoing to further the technology's application. An understanding of the contributions, both realized and potential, that biotechnology makes to agriculture is critical to the unfolding public discussion of the technology.

Study Purpose

Biotechnology has been widely discussed over the past several years, and there has been considerable examination of the impact of biotechnology in commodity crops such as corn, cotton and soybeans in major growing regions. Discussion has largely focused on the impact of insect and herbicide resistant crops. However, there has been little discussion about the potential impact of biotechnology on less widely grown crops, and no evaluation of potential impact of fungus, virus, bacteria and nematode resistant crops, which are being developed by various research organizations.

In February 2001, the National Center for Food and Agricultural Policy (NCFAP) received a grant from The Rockefeller Foundation to estimate the potential impacts of 10 biotech pest-management cultivars. Supplemental funds provided by the Council for Biotechnology Information (CBI), Biotechnology Industry Organization (BIO), CropLife America (CLA), Grocery Manufacturers of America (GMA) and Monsanto allowed the study to expand, to include 40 cultivars that have been developed or are being developed to manage agricultural pests in 27 crops.

Methodology

The study examined 40 specific case studies in which biotech cultivars have been employed or are in development to address pest-control issues. The report is limited to cases for which successful transformation has occurred and for which there are at least preliminary results on performance for pest management. The case studies are representative of how the biotech cultivars would be used in agriculture, but the case studies may not represent the entire impact of the cultivar. For example, alfalfa is grown in nearly every state, but the case study of biotech alfalfa only examines California, the leading alfalfa-producing state.

The case studies were selected and impact estimates were calculated using the following six methodological steps:

1. NCFAP reviewed scientific journals, data from government and university research facilities and commodity publications for articles on biotech use in pest management.

2. NCFAP interviewed researchers developing the cultivars to verify research success, and they were asked to provide summaries of their research.

3. States in which biotech cultivars would provide pest-management benefits were identified. Generally these were the states with the largest acreage or states where the pest problem was most significant.

4. NCFAP analyzed the existing status of pest problems and management practices and quantified existing pesticide use, crop losses and management costs.

5. Potential impacts were analyzed in four categories: changes in production costs, changes in pesticide use, changes in production or yield and the value of the production.

6. A written case-study analysis was sent to outside reviewers for comment. Reviewers' comments were incorporated into the case study reports.

Selecting the Case Studies

Only biotech cultivars to be used in pest management were examined for this report. The full report including each case study is available on NCFAP's web site (www.NCFAP.org).

Categories of pest control The 40 pest-management case studies are classified according to six pest-control criteria:

- Insect resistance (IR): 11 case studies
- Herbicide tolerance (HT): 14 case studies
- Nematode resistance (NR): One case study
- Bacteria resistance (BR): Three case studies
- Virus resistance (VR): Nine case studies
- Fungus resistance (FR): Three case studies

For field corn and cotton, there are multiple insect resistant cultivars treated as separate case studies. For example, cultivars that control corn borer or corn rootworm are treated separately.

(NOTE: The numbers above total 41 because one cultivar, which expresses insect and virus resistant traits, is counted in both categories. In the summary tables, it is counted only once in the insect resistance category.)

Categories of adoption status Additionally, each case study is classified according to its adoption status. These categories are:

- Adopted (A) — Eight case studies estimate the impacts that have occurred as a result of current (2001) transgenic crop adoption for pest management in the United States. The case studies approximate the changes in pesticide use, crop production and costs of production that occurred in 2001 as a result of adoption compared with what would have occurred had biotech crops not been adopted.

- Approved but not adopted (AA) — Four case studies, which involve cultivars that are registered and available but not yet adopted by growers, calculate the impacts that would have occurred in 2001 had growers planted them. The impact estimates quantify foregone benefits in terms of production volume, production costs and pesticide use impacts that are as yet unrealized.

- Under development for current pest problems (UDCP) — Twenty-four case studies quantify the yield, cost-reduction and pesticide-reduction impacts that would have occurred in 2001 had U.S. growers planted biotech cultivars that are under development to address existing pest problems.

- Under development for future pest problems (UDFP) — Four case studies quantify the potential impacts of biotech cultivars being developed to manage pest problems that are expected to occur in the future, such as crop diseases that have not yet become a major difficulty for U.S. growers. To evaluate their expected impact, NCFAP calculated what input costs and yield reductions would have been incurred in 2001 if the pests were present.

Evaluating the Impact

Four aggregate measures were quantified in all case studies:

- **Changes in production costs** were calculated by determining which current practices would be affected, resulting in savings, as well as by projecting an assumed cost of purchasing the biotech seeds.
- **Changes in crop yield** were estimated depending on the effectiveness of the biotech product in preventing pest losses compared with the technology it would likely replace.
- **Changes in crop value** similarly were estimated based on the expected yield changes, plus or minus changes in production costs, leading to an overall net value.
- **Changes in pesticide use** were quantified if the biotech cultivar was likely to replace current use for the target pest.

The combined impact of the 40 case studies paints a picture of 2001 that might have been. Eight cultivars, of course, were adopted and were widely planted in 2001, so their impact reflects what actually occurred. Others were available but were not planted, and others are being developed to address pest problems that were present in 2001. These case studies reflect what impact they would have had in addressing pest problems that existed in 2001. Four case studies reflect anticipated impacts on pest problems that could affect U.S. growers in the near future. To calculate their expected impact, it was assumed that the anticipated pests were present in 2001 and would have to be managed with technologies that were available. For these cases, NCFAP assumed growers used traditional control methods for the emerging pest.

The 40 Case Studies

Table 1 lists the 40 case studies included in the report and identifies the type of case study by biotech trait: insect resistant (IR), herbicide tolerant (HT), bacteria resistant (BR), fungus resistant (FR), nematode resistant (NR) and virus resistant (VR). In addition, its adoption status is delineated: adopted (A), approved but not adopted (AA), under development for current pest problems (UDCP), and under development for future pest problems (UDFP). The states that are, or would be, impacted by the biotech cultivars are also listed. For tracking purposes, each case study has been assigned a reference number, which is used throughout this executive summary and full report.

Table 1: The 40 Biotech Crop Case Studies

Case Study Reference #	Crop	Type	Geographic Region	Status	Description of Impact
1	Papaya	VR	HI	A	When an epidemic of ring spot virus ravaged the Hawaiian papaya industry, production declined by 45 percent. Virus resistant trees, which began producing fruit in 1998, reversed the decline.
2	Squash	VR	FL/GA	A	Four mosaic viruses can cause growers to lose up to 20 percent of their summer squash production in Florida and Georgia. Transgenic squash protects against the viruses.
3	Peanut	VR	GA	UDCP	A virus, transmitted by insects, can reduce peanut yields significantly. The virus can be controlled by spraying insecticides to kill the insect. The University of Georgia is developing a virus resistant variety.
4	Peanut	IR	GA	UDCP	The lesser cornstalk borer causes damage to peanuts and allows harmful mycotoxins to form. An insect resistant variety is being developed to control the pest.
5	Tomato	VR	FL	UDCP	Two viruses can cost Florida tomato growers yield losses of 20 percent or more ($140 million). The virus is spread by white flies, so pesticides are used to control the insects. The University of Florida is researching tomato lines resistant to the viruses. Trials have shown yields 1.7 times higher than conventional tomatoes in the presence of virus pressure.
6	Tomato	HT	CA	UDCP	While 90 percent of California tomatoes are treated with herbicides, weeds such as nightshade and nutsedge require extensive fumigant use and hand weeding. Herbicide tolerant tomatoes would withstand applications of glufosinate herbicide, which controls these important weeds at a lower cost.

Type: IR, insect resistance; HT, herbicide tolerance; NR, nematode resistance; BR, bacteria resistance; VR, virus resistance; FR, fungus resistance.
Status: A, adopted; AA, approved but not adopted; UDCP, under development for current pest problems; UDFP, under development for future pest problems.

Table 1:	The 40 Biotech Crop Case Studies				
Case Study Reference #	Crop	Type	Geographic Region	Status	Description of Impact
7	Lettuce	HT	CA	UDCP	Weed control in California lettuce requires extensive herbicide use. Lettuce made tolerant to glyphosate herbicide would allow growers to control weeds with fewer pounds of pesticides.
8	Strawberry	HT	CT/ME/MD MA/NH/NJ NY/PA/VT	UDCP	Extensive hand weeding of strawberry crops and up to three herbicide applications per season cost as much as $500 per acre. Because of costs, strawberry acreage has been declining in nine northeastern states. Strawberries made resistant to glyphosate herbicide would save growers $242 per acre.
9	Pineapple	NR	HI	UDCP	Nematodes (microscopic root-eating organisms) reduce Hawaiian pineapple yields by as much as 60 percent. To control nematodes, growers rotate to fallow land and use soil fumigants. Pineapple plants modified with a rice gene have demonstrated resistance to nematodes.
10	Broccoli	IR	CA	UDCP	Preventing insect contamination of broccoli heads is essential to marketability. Broccoli modified to contain insect protection proteins from Bacillus thuringiensis (Bt) have demonstrated control of important pests without using insecticides.
11	Citrus	VR	TX	UDFP	The rootstock on which 98 percent of Texas citrus is grown is susceptible to citrus tristeza virus, which has devastated orchards in Latin America. The virus is spread by the brown citrus aphid, which has not yet reached Texas. When it does, it is expected that the virus will destroy many Texas trees. Researchers at Texas A&M are testing a virus resistant variety.
12	Citrus	BR	FL	UDFP	Citrus canker reduces yields and downgrades quality. Efforts to eradicate it in Florida led to the destruction of 1.5 million trees. Biotechnology is being used to investigate canker resistance.
13	Sweet Corn	IR	FL	AA	Fall armyworm and corn earworm are major pests in Florida sweet corn. Insect resistant sweet corn is expected to reduce insecticide applications from 12 per year to only two, while increasing yields. The corn is commercialized, but not yet planted by growers.
14	Sweet Corn	HT	WI	AA	In the last decade, sweet corn production in Wisconsin has declined by 45 percent. Herbicides registered for sweet corn are limited, cause crop injury, and groundwater regulations preclude the use of effective herbicides. Regional food-processing facilities are moving to other states. Sweet corn tolerant of the herbicide glufosinate would provide effective weed control.
15	Stone Fruit	VR	PA	UDFP	Plum pox, an aphid-borne virus, attacks stone fruits such as plums, peaches and nectarines, causing them to fall off trees prematurely. Pennsylvania has declared a quarantine, spent $5.1 million in eradication efforts and destroyed 900 acres of trees. Through biotechnology, a virus resistant variety has been developed by the USDA.
16	Raspberry	VR	OR/WA	UDCP	Raspberry bushy dwarf virus renders the berries crumbly and unfit for the fresh market. The virus spreads in pollen, so the only "cure" is to destroy infected plants. In 1996, 84 percent of the raspberry fields in northern Washington were infected. Because of the virus, the average economic life of raspberry bushes has decreased from 15 to five years. A collaborative effort between the federal government and industry has developed a virus resistant variety.

Type: IR, insect resistance; HT, herbicide tolerance; NR, nematode resistance; BR, bacteria resistance; VR, virus resistance; FR, fungus resistance.
Status: A, adopted; AA, approved but not adopted; UDCP, under development for current pest problems; UDFP, under development for future pest problems.

Table 1: The 40 Biotech Crop Case Studies

Case Study Reference #	Crop	Type	Geographic Region	Status	Description of Impact
17	Potato	IR/VR	OR/WA/ID	AA	Two major potato pests in the Northwest are Colorado potato beetle and green peach aphid. The beetle devours leaves, reducing yield. The aphid spreads the devastating potato leaf roll virus. Efforts to control the pests have involved intensive insecticide use for decades, without complete effectiveness. A commercially available potato controls the beetle and is resistant to the virus spread by the aphid, potentially replacing insecticides, but it is not yet planted by growers.
18	Potato	FR	OR/WA/ID	UDCP	Verticillium wilt infects the water-conducting system of potatoes, resulting in symptoms of severe drought and reducing yields by up to 40 percent. The disease is controlled by applying a costly soil fumigant. An anti-fungal gene from alfalfa has been transferred to Russet Burbank potatoes, reducing fungal levels six-fold in field trials.
19	Potato	HT	OR/WA/ ID	UDCP	Potatoes are a slow-growing crop that provides little competition for weeds. Weed control in the Northwest depends on cultivation and timely formation of hills, plus one or more herbicide applications. Post-emergent herbicides are limited because of risk of harming the potato plant. Glyphosate tolerant potatoes provide an effective weed-management tool that can prevent yield losses.
20	Sugarbeet	HT	CA/CO/ID MI/MN/MT NE/ND/OR WA/WY	AA	U.S. sugarbeet growers typically make three to four herbicide applications per year, each consisting of multiple active ingredients. Herbicide tolerant sugarbeets, introduced in 1999, allow for equivalent weed control with only two applications of one active ingredient, glyphosate. Growers' costs for tillage and herbicide application would be reduced significantly, but sugarbeets are not yet planted.
21	Grape	BR	CA	UDFP	Pierce's disease is a bacterial infection that clogs water-carrying arteries of grapevines. It is spread by insects known as sharpshooters. In the 1990s, a new species of sharpshooter invaded California, and the disease spread more rapidly. In Riverside County alone, more than 300 acres were destroyed. The disease potentially could reach all California grapes. Several potential sources of resistance have been identified, including genes from silkworm pupae.
22	Apple	BR	CA/ID/MD MA/MI/MO NJ/NY/NC OH/OR/PA VA/WA/WV	UDCP	Fire blight outbreaks, each costing millions of dollars, are becoming more frequent as fire blight populations develop resistance to foliar antibiotics. A resistant variety is being tested, which could replace antibiotic sprays in orchards and lower growers' costs.
23	Sunflower	FR	ND/KS MN/SD	UDCP	An estimated 8 percent of sunflower production is lost each year to Sclerotinia diseases, with individual growers losing as much as 80 percent of their yield in epidemic years. A wheat gene, which produces a detoxifying protein, has been transferred to sunflowers, resulting in plants that show resistance to the diseases.
24	Canola	HT	ND	A	Weed control is important in canola because the presence of weed seeds can reduce the consumer quality of canola oil and the feed quality of canola meal. Herbicide use is the cornerstone of weed management in canola because narrow row planting inhibits cultivation. Canola made resistant to glyphosate herbicide provides a broader range of weed control than alternatives and enables growers to reduce herbicide use by about 0.7 pounds per acre and save $15 per acre in herbicide costs.

Type: IR, insect resistance; HT, herbicide tolerance; NR, nematode resistance; BR, bacteria resistance; VR, virus resistance; FR, fungus resistance.
Status: A, adopted; AA, approved but not adopted; UDCP, under development for current pest problems; UDFP, under development for future pest problems.

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Case Study Reference #	Crop	Type	Geographic Region	Status	Description of Impact
25	Soybean	IR	GA/AL/MS LA/SC	UDCP	Southern soybean growers spend an estimated $10 million per year on insecticides. Researchers at the University of Georgia are developing a line of soybeans that is resistant to two important soybean pests.
26	Soybean	HT	U.S.[1] (31 states)	A	U.S. soybean farmers rapidly adopted glyphosate tolerant soybeans because of significant cost savings in comparison to traditional weed-control programs using tillage and alternative herbicides. Effective alternative herbicide programs have been developed. However, if soybean growers were to switch from planting the biotech cultivar and substitute with alternatives, costs would increase by $20/acre, and herbicide use would increase by .57 pounds of active ingredients per acre.
27	Rice	HT	CA/TX/MS AR/MO/LA	UDCP	Many U.S. rice fields are plagued with weeds such as red rice that are increasingly tolerant to available herbicides. As a result, large quantities of herbicides are used, and costly flooding and tillage of fields is necessary for weed control. If rice fields were planted with glufosinate tolerant cultivars, herbicide use amounts and costs would decline significantly.
28	Field Corn	IR (1)	U.S.[2] (36 states)	A	Bt corn has been planted on acres that have traditionally been infested with high populations of the European and Southwestern corn borers, and as a result of improving control of these pests, U.S. corn production has increased without the need for additional insecticide sprays.
29	Field Corn	IR (2)	GA/IL/IN KS/KY/LA MO/MS OH/TX	UDCP	Fall armyworms, black cutworms and corn earworms can cause large yield losses. A type of Bt field corn is under development to control infestations of these pests as well as both the European and Southwestern corn borers, which could further reduce the need for insecticide use.
30	Field Corn	IR (3)	CO/IA/IL IN/KS/MD MI/MN MO/ND NE/NY/OH OK/PA/SD TX/WI	UDCP	Corn rootworms are the most serious insect pest in U.S. field corn. For many years, corn rootworms have been controlled with crop rotation and soil insecticides. In recent years, crop rotation has failed to control rootworm damage in some areas, resulting in economic losses. Transgenic Bt corn for rootworm control, coated with insecticides to control secondary pests, could eliminate the need of an at-plant soil insecticide on 23 million acres.
31	Field Corn	HT	U.S.[3] (33 states)	A	Adoption of herbicide tolerant corn technology has been largely driven by improved control of troublesome weed species for which there are weaknesses in conventional herbicide programs. Growers have reduced the rates of soil-applied herbicide and are using glyphosate or glufosinate to effectively control weeds that emerge. Replacing the current herbicide program results in a reduction in herbicide use and cost to growers.
32	Cotton	IR (1)	AL/AZ/AR CA/FL/GA LA/MS/MO NM/NC OK/SC/TN	A	Bt cotton varieties were introduced in 1996, providing control of three major cotton insect pests (tobacco budworm, cotton bollworm and pink bollworm). The adoption of Bt varieties was extremely rapid in states that experienced resistance problems. Bt cotton is credited with saving the cotton industry in Alabama. This technology reduces yield losses, reduces insecticide use, and provides cost savings.

[1] Alabama, Arkansas, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Virginia, West Virginia, Wisconsin

[2] Alabama, Arkansas, Arizona, Colorado, Connecticut, Delaware, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Massachusetts, Maryland, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Jersey, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Virginia, Vermont, West Virginia, Wisconsin

[3] Arkansas, Arizona, California, Colorado, Connecticut, Delaware, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Massachusetts, Maryland, Michigan, Minnesota, Missouri, Nebraska, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, South Dakota, Tennessee, Texas, Utah, Virginia, Vermont, Wisconsin, Wyoming

Table 1:	The 40 Biotech Crop Case Studies				
Case Study Reference #	Crop	Type	Geographic Region	Status	Description of Impact
33	Cotton	IR (2)	AL/AZ/AR CA/FL/GA LA/MS/MO NM/NC OK/SC/TN TX/VA	UDCP	Transgenic Bt cotton has been commercially available since 1996. It has demonstrated remarkable control of some pests, particularly the tobacco budworm and the pink bollworm. Control of the budworm has been less dependable, and economically damaging infestations of this pest can occur in Bt cotton. Other common pests such as fall armyworms, beet armyworms and soybean loopers are even more tolerant than bollworms. The addition of a second Bt protein expressed in cotton provides satisfactory control of beet armyworms, fall armyworms and soybean loopers. Also, efficacy is improved against bollworms.
34	Cotton	HT	AL/AZ/AR CA/FL/GA LA/MS/MO NC/OK/SC TN/TX/VA	A	Weeds dramatically reduce cotton yields. In 1995, typical U.S. cotton acres were sprayed with an average of three herbicides on three occasions. Since the introduction of herbicide tolerant varieties, growers have reduced herbicide applications and saved millions of dollars due to less hand weeding and cultivation of fields.
35	Alfalfa	HT	CA	UDCP	When alfalfa bales are weedy, the value is discounted. The annual discount due to weediness is estimated at $21 million per year in California. Weed control in seedling alfalfa often is unattainable with available herbicides. Researchers have developed varieties that are tolerant of glyphosate at all stages. Field tests are underway.
36	Barley	FR	ND	UDCP	Since 1993, epidemics of fusarium head blight or scab have adversely affected North Dakota malting barley. Yield has been reduced by 25 percent, but value has declined by 40 percent due to the presences of harmful mycotoxins caused by fungal infections. Two anti-toxin genes have been introduced into barley and are being tested.
37	Wheat	HT	ND/SD MN/MT	UDCP	It has been estimated that 33 percent of spring wheat in Montana, Minnesota, North Dakota and South Dakota is not treated with herbicides to control Canada thistle, a key weed problem, because cost outweighs benefits, resulting in an average yield loss of four bushels per acre. It is estimated that glyphosate tolerant wheat would control all major weeds in wheat and enable growers to increase their income by $12 per acre.
38	Wheat	VR	OR/WA/ID	UDCP	Two viruses in the Pacific Northwest pose a serious risk to wheat crops. They can reduce yield by up to 90 percent in a heavily infested field. The viruses are spread by aphids and mites. Growers seek to reduce the threat by delaying planting or using insecticides. Delayed planting can result in yield losses up to 13 percent. Field tests are underway on wheat varieties resistant to the viruses.
39	Eggplant	IR	NJ	UDCP	The Colorado potato beetle is a major pest in eggplant production and is controlled by use of a systemic insecticide. Eggplant that expresses a protein from the Bt bacterium shows resistance to the beetle in field trials.
40	Sugarcane	HT	LA	UDCP	Weed control in Louisiana sugarcane is particularly troublesome because of the presence of tough perennial grasses such as johnsongrass and bermudagrass, which can reduce yield up to 50 percent. Because sugarcane is also a grass, it is susceptible to many herbicides that could provide control. Sugarcane resistant to glyphosate herbicide would replace the herbicides currently used in sugarcane and provide more effective control of important weeds.

Type: IR, insect resistance; HT, herbicide tolerance; NR, nematode resistance; BR, bacteria resistance; VR, virus resistance; FR, fungus resistance.
Status: A, adopted; AA, approved but not adopted; UDCP, under development for current pest problems; UDFP, under development for future pest problems.

RESULTS

The impact of biotech crops was calculated for each of the four impact categories: adopted, approved but not adopted, under development for current pest problems and under development for future pest problems. Each of the 40 cultivars provides value equal to or greater than the pest-control practice it would replace. Value was calculated by determining any expected yield change plus or minus any change in growers' costs.

Impact of biotech crops adopted and planted in 2001

Table 2 displays impact estimates for the eight case studies where adoption has occurred. Four of the adopted cultivars resulted in increased yield because they provided more effective control of pests than the control methods they replaced. The other four show a decrease in grower costs, which is represented by a minus sign in the column. When a minus sign is used to indicate reduced costs, the reduction amount is added to the value of the yield to determine net value. Likewise, if grower costs increase, the increase is subtracted to determine net value.

Yield impact The largest increases in production in 2001 occurred from planting insect resistant corn (3.5 billion pounds) and insect resistant cotton (185 million pounds). Before insect protected crops were developed, cotton growers relied on chemical sprays to control bollworms and budworms. The sprays, which were not as effective as in-plant protection, allowed a sizeable percentage of insects to survive, thereby reducing yield. In corn, the European corn borer and Southwestern corn borer are major pests not controlled readily because the pest tunnels into the stalk. Corn with in-plant protection provides nearly 100 percent season-long control of corn borers, resulting in increased yields.

Economic impact The greatest economic impact of adopted crops was lower production costs for growers. Herbicide tolerant soybeans provided the greatest savings ($1 billion), followed by herbicide tolerant cotton ($133 million), and herbicide tolerant corn ($58 million). Overall, the adoption of the transgenic cultivars improved growers' bottom lines by $1.5 billion in 2001. The development of herbicide tolerant crops enabled growers to use one herbicide rather than three or four to control weeds. Growers were also able to make fewer trips across their fields, reducing production costs. The introduction of herbicide tolerant crops also resulted in lower overall herbicide costs and savings in hand-weeding costs.

Table 2: Impact of Biotech Crops Adopted and Planted in 2001

Case Study	Crop	Type	Production (per year)			Total Net Value (000$/yr.)	Pesticide Use (lbs. AI/yr.)†	Acreage
			Volume (000 lbs.)	Value (000$)	Costs (000$)			
1	Papaya	VR	+53,000	+17,000	0	+17,000	0	1,600
2	Squash	VR	+6,000	+2,000	+375	+1,625	0	5,000
24	Canola	HT	0	0	-11,000	+11,000	-531,000	871,000
26	Soybean	HT	0	0	-1,010,765	+1,010,765	-28,703,001	50,016,000
28	Field Corn	IR (1)	+3,540,992	+126,466	+1,110	+125,356	-2,603,456	14,927,000
31	Field Corn	HT	0	0	-58,050	+58,050	-5,805,000	5,805,000
32	Cotton	IR (1)	+ 185,373	+115,002	+12,034	+102,968	-1,870,100	5,144,000
34	Cotton	HT	0	0	-132,676	+132,676	-6,169,000	9,301,000
Total			+3,785,365	+260,468	-1,198,972	+1,459,440	-45,681,557	———††

Type: IR, insect resistance; HT, herbicide tolerance; NR, nematode resistance; BR, bacteria resistance; VR, virus resistance; FR, fungus resistance.
Status: A, adopted; AA, approved but not adopted; UDCP, under development for current pest problems; UDFP, under development for future pest problems.

† AI refers to active ingredients.

†† NOTE: Acreage is not totaled because, in some cases, cultivars with multiple traits could be planted on the same acre.

Table 3:	Potential Impact of Biotech Crops Approved but Not Adopted in 2001							
Case Study	Crop	Type	Production (per year)			Total Net Value (000$/yr.)	Pesticide Use (lbs. AI/yr.)†	Acreage
			Volume (000 lbs.)	Value (000$)	Costs (000$)			
13	Sweet Corn	IR	+22,000	+3,900	-1,300	+5,200	-112,000	32,000
14	Sweet Corn	HT	+72,000	+2,400	+1,400	+1,000	+16,200	30,000
17	Potato	IR/VR	+1,000,000	+52,000	-6,700	+58,700	-1,450,000	621,000
20	Sugarbeet	HT	0	0	-93,300	+93,300	+963,000	1,500,000
Total			+1,094,000	+58,300	-99,900	+158,200	-582,800	———††

Type: IR, insect resistance; HT, herbicide tolerance; NR, nematode resistance; BR, bacteria resistance; VR, virus resistance; FR, fungus resistance.
Status: A, adopted; AA, approved but not adopted; UDCP, under development for current pest problems; UDFP, under development for future pest problems.
† AI refers to active ingredients.
†† NOTE: Acreage is not totaled because, in some cases, cultivars with multiple traits could be planted on the same acre.

Pesticide-use impact In two instances, pesticide use remained unchanged compared with previous practices. In six of the cases, pesticide use declined. The largest decline was a result of herbicide tolerant soybean (28.7 million pounds) and herbicide tolerant cotton (6.2 million pounds). Overall, U.S. pesticide use was 45.6 million pounds lower in 2001 than it would have been without biotech crops.

Potential impact of biotech crops approved but not adopted in 2001

Table 3 displays the foregone impact estimates for the four case studies representing biotech cultivars that have been approved for use by the federal government but were not adopted by growers in 2001.

Yield impact The most significant foregone yield improvement was seen in potato production, where 1 billion pounds of yield loss could have been prevented in 2001 if growers had planted a cultivar that is resistant to insects and viral disease. The potato plants control the Colorado potato beetle, which defoliates potatoes. It also prevents the deadly potato leaf roll virus.

Economic impact It is anticipated that if these four approved crops had been planted in 2001, U.S. growers would have improved their bottom line by $158 million. The greatest impact would have been in sugarbeet production, where growers must apply three or four different herbicides three to four times per season to kill different weed species.

Pesticide-use impact The four approved but not adopted crops could have lowered pesticide use by 582,800 pounds in 2001 had they been planted. A 1.4 million pound reduction in potato insecticide use would have been somewhat offset by increases in sugarbeet and sweet corn herbicide use. Herbicide tolerant crops almost always reduce the number of herbicide active ingredients that must be applied and the number of applications that must be made. In some cases, the herbicides that are replaced are applied at a lower use rate than herbicides to which the crops have been made resistant.

Potential impact of biotech crops under development to address current pest problems

Table 4 displays the estimates for the impact that could have been realized if 24 cultivars being developed to address current pest problems had been available in 2001. The 24 cultivars combined could have reduced growers' costs by $121 million. Based on data available, there does not appear to be a change in net value for three cultivars, insect resistant eggplant, herbicide resistant lettuce and rootworm resistant corn. However, if growers were to adopt those three cultivars, there would be a pesticide reduction of more than 14 million pounds per year.

Yield impact Potential increases in production were quantified for fungus resistant barley (1.4 billion pounds), herbicide tolerant wheat (1.4 billion pounds), and herbicide tolerant sugarcane (1.4 billion pounds) because the transgenic cultivars are expected to provide more effective control of pests, which are currently reducing yields. Biotech barley, for example, could control fusarium head blight, which reduces yield by about 25 percent and produces fungal toxins, which decrease the grain value by about 40 percent. Herbicide tolerant wheat could control weeds that decrease yields by about four bushels per acre.

Economic impact The largest decreases in cost could have resulted from herbicide tolerant rice adoption ($49 million) and herbicide tolerant tomato adoption ($30 million). Current herbicide options do not control all weeds in rice and tomato fields. As a result, extensive hand weeding, field flooding, tillage and fumigation are required.

Pesticide-reduction impact The 24 products in development to address current pest issues could have reduced pesticide use in 2001 by a combined 56 million pounds. Significant potential reductions were quantified for fungus resistant potatoes (28 million pounds), herbicide tolerant tomatoes (4.2 million pounds) and nematode resistant pineapples (1.4 million pounds).

Table 4: Potential Impact of Biotech Crops Under Development for Current Pest Problems

Case Study	Crop	Type	Production (per year)			Total Net Value (000$/yr.)	Pesticide Use (lbs. AI/yr.)†	Acreage
			Volume (000 lbs.)	Value (000$)	Costs (000$)			
3	Peanut	VR	+59,000	+17,000	0	+17,000	0	540,000
4	Peanut	IR	0	+900	-600	+1,500	-47,520	540,000
5	Tomato	VR	0	0	-4,200	+4,200	-64,600	42,000
6	Tomato	HT	0	0	-30,000	+30,000	-4,200,000	289,000
7	Lettuce	HT	0	0	0	0	-140,000	214,000
8	Strawberry	HT	0	0	-1,265	+1,265	-13,851	5,200
9	Pineapple	NR	0	0	-2,100	+2,100	-1,427,790	21,000
10	Broccoli	IR	+3,400	+1,200	-2,659	+3,859	-11,623	82,000
16	Raspberry	VR	+10,000	+11,200	-2,500	+13,700	-371,000	7,600
18	Potato	FR	0	0	-18,000	+18,000	-28,400,000	621,000
19	Potato	HT	+521,640	+26,000	+20,000	+6,000	+465,000	621,000
22	Apple	BR	+251,000	+35,600	-2,794	+38,394	-21,800	204,175
23	Sunflower	FR	+260,000	+17,200	+4,780	+12,420	0	2,390,000
25	Soybean	IR	+54,000	+4400	-2,400	+6,800	-295,000	1,280,000
27	Rice	HT	0	0	-49,168	+49,168	-3,828,000	943,000
29	Field Corn	IR (2)	+725,648	+25,796	+6,323	+19,473	-237,435	2,575,000
30	Field Corn	IR (3)	0	0	0	0	-14,496,000	23,402,000
33	Cotton	IR (2)	+37,454	+22,468	-23,908	+46,376	-986,655	5,144,000
35	Alfalfa	HT	0	+21,000	+3,400	+17,600	+200,000	1,000,000
36	Barley	FR	+1,440,000	+100,000	-360	+100,360	-4,500	3,000,000
37	Wheat	HT	+1,416,000	+70,800	0	+70,800	0	5,900,000
38	Wheat	VR	+913,920	+38,895	-828	+39,723	-82,800	4,600,000
39	Eggplant	IR	0	0	0	0	-208	800
40	Sugarcane	HT	+1,400,000	+16,000	-15,200	+31,200	-1,800,000	460,000
Total			+7,092,062	+408,459	-121,479	+529,938	-55,763,782	———††

Type: IR, insect resistance; HT, herbicide tolerance; NR, nematode resistance; BR, bacteria resistance; VR, virus resistance; FR, fungus resistance.
Status: A, adopted; AA, approved but not adopted; UDCP, under development for current pest problems; UDFP, under development for future pest problems.
† AI refers to active ingredients.
†† NOTE: Acreage is not totaled because, in some cases, cultivars with multiple traits could be planted on the same acre.

In each of those cases, biotech cultivars would enable growers to reduce their use of gas fumigants, which are injected into the soil to control soil-borne diseases, weed seeds and nematodes (microscopic, root-eating organisms). The adoption of rootworm resistant corn would substitute for 14 million pounds of insecticide, while herbicide tolerant rice would lower herbicide use by 3.8 million pounds.

Potential impact of biotech crops under development to address future pest problems
Table 5 displays the potential economic impact estimates for the four cultivars that are under development that have the potential to manage developing or worsening pest problems in the United States. These cultivars have the potential to prevent the spread of crop diseases, which are not yet a serious problem but likely will be in the near future. To quantify their potential impact, it was assumed that expected pests were in fact present in 2001 and had to be managed with existing technology and practices. Projected yields, cost savings and pesticide reduction were calculated.

Yield impact The impact estimates indicate that the transgenic cultivars could prevent the loss of 2.5 billion pounds of production — mainly citrus crops, which are at risk from viral and bacterial diseases. One such disease, citrus tristeza virus, is spread by an aphid, which has just recently spread from South America to Florida and northern Mexico. It is expected to affect susceptible citrus in Texas soon. Other diseases threaten grapes, plums, peaches and nectarines.

Economic impact The anticipated lost production from future diseases is valued at $162 million per year. Without the transgenic cultivars, it is expected that growers would spend $161 million per year to manage the pest problems, costs that would be saved with the transgenic cultivars. In total, transgenic crops would prevent anticipated grower losses of approximately $324 million per year.

Table 5: Potential Impact of Biotech Crops Under Development for Future Pest Problems

Case Study	Crop	Type	Production (per year)			Total Net Value (000$/yr.)	Pesticide Use (lbs. AI/yr.)†	Acreage
			Volume (000 lbs.)	Value (000$)	Costs (000$)			
11	Citrus	VR	+904,000	+48,000	0	+48,000	0	30,000
12	Citrus	BR	+1,560,000	+97,650	-56,700	+154,350	-1,638,000	762,000
15	Stone Fruit	VR	+60,000	+17,000	0	+17,000	0	7,200
21	Grape	BR	0	0	-105,000	+105,000	-59,000,000	790,000
Total			**+2,524,000**	**+162,650**	**-161,700**	**+324,350**	**-60,638,000**	———††

Table 6: Total Impact of Biotech Crops by Status

Status	Production (per year)			Total Net Value (000$/yr.)	Pesticide Use (lbs. AI/yr.)†
	Volume (000 lbs.)	Value (000$)	Costs (000$)		
Adopted	+3,785,365	+260,468	-1,198,972	+1,459,440	-45,681,557
Approved but not adopted	+1,094,000	+58,300	-99,900	+158,200	-582,800
Under development for current pest problems	+7,092,062	+408,459	-121,479	+529,938	-55,763,782
Under development for future pest problems	+2,524,000	+162,650	-161,700	+324,350	-60,638,000
Total	**+14,495,427**	**+889,877**	**-1,582,051**	**+2,471,928**	**-162,666,139**

Type: IR, insect resistance; HT, herbicide tolerance; NR, nematode resistance; BR, bacteria resistance; VR, virus resistance; FR, fungus resistance.
Status: A, adopted; AA, approved but not adopted; UDCP, under development for current pest problems; UDFP, under development for future pest problems.
† AI refers to active ingredients.
†† NOTE: Acreage is not totaled because, in some cases, cultivars with multiple traits could be planted on the same acre.

Pesticide-use impact Without the adoption of the transgenic crops, growers would use an additional 60 million pounds of pesticides per year to manage these pest problems. Costly applications of insecticides and copper bactericides account for nearly all of this.

Total impact of biotech crops by status

Table 6 summarizes the economic and pesticide-use impacts according to the status of the transgenic cultivar. The table shows that eight biotech products adopted by growers increased yields by 3.8 billion pounds in 2001, reduced growers' cost by $1.2 billion and cut pesticide use by 45.6 million pounds. Products in development or not yet adopted have potential to add another $1 billion in value to U.S. farmers.

Yield impact These 40 examples are estimated to have the potential for generating 14 billion more pounds of food and fiber than would otherwise be produced.

Economic impact The value of the increased production is estimated at $890 million per year with an additional economic benefit based on reduced grower costs. The 40 biotech cultivars could reduce production costs by $1.6 billion annually. On the whole, U.S. growers' bottom lines would increase by $2.5 billion per year with the adoption of these transgenic cultivars.

Pesticide-use impact Pesticide use would be reduced by 163 million pounds with the adoption of these transgenics.

Total impact of biotech crops by type

Table 7 shows aggregate impact estimates by type of biotech crop. With the exception of the nematode resistance case study, all of the cultivars have the potential for increasing crop production volume and value as a result of more effective pest control. Estimates of reduced grower costs ($1.6 billion) and positive impacts on growers net income ($2.5 billion) are dominated by savings as a result of herbicide tolerant crops, the bulk of which is due to the adoption of herbicide tolerant soybeans ($1 billion). Savings result from the large number of acres where the soybean technology has been adopted (50 million acres). Reduction in the use of pesticides is expected as a result of adoption of all types of biotech cultivars.

Total impact of biotech crops by state

Table 8 displays the economic and pesticide use impact estimates by state. Impact estimates have been calculated for 47 states. The states with the highest potential economic impacts as a result of adoption are California and North Dakota. California represents 42 percent of the total potential impact of reduced pesticide use: 66 million pounds

Table 7: Total Impact of Biotech Crops by Type

Type	Production (per year)			Total Net Value (000$/yr.)	Pesticide Use (lbs. AI/yr.)†
	Volume (000 lbs.)	Value (000$)	Costs (000$)		
Insect Resistant	+5,568,867	+352,132	-18,100	+370,232	-22,109,997
Herbicide Tolerant	+3,409,640	+136,200	-1,376,624	+1,512,824	-49,545,652
Virus Resistant	+2,005,920	+151,095	-7,153	+158,248	-518,400
Fungus Resistant	+1,700,000	+117,200	-13,580	+130,780	-28,404,500
Bacteria Resistant	+1,811,000	+133,250	-164,494	+297,744	-60,659,800
Nematode Resistant	0	0	-2,100	+2,100	-1,427,790
Total	**+14,495,427**	**+889,877**	**-1,582,051**	**+2,471,928**	**-162,666,139**

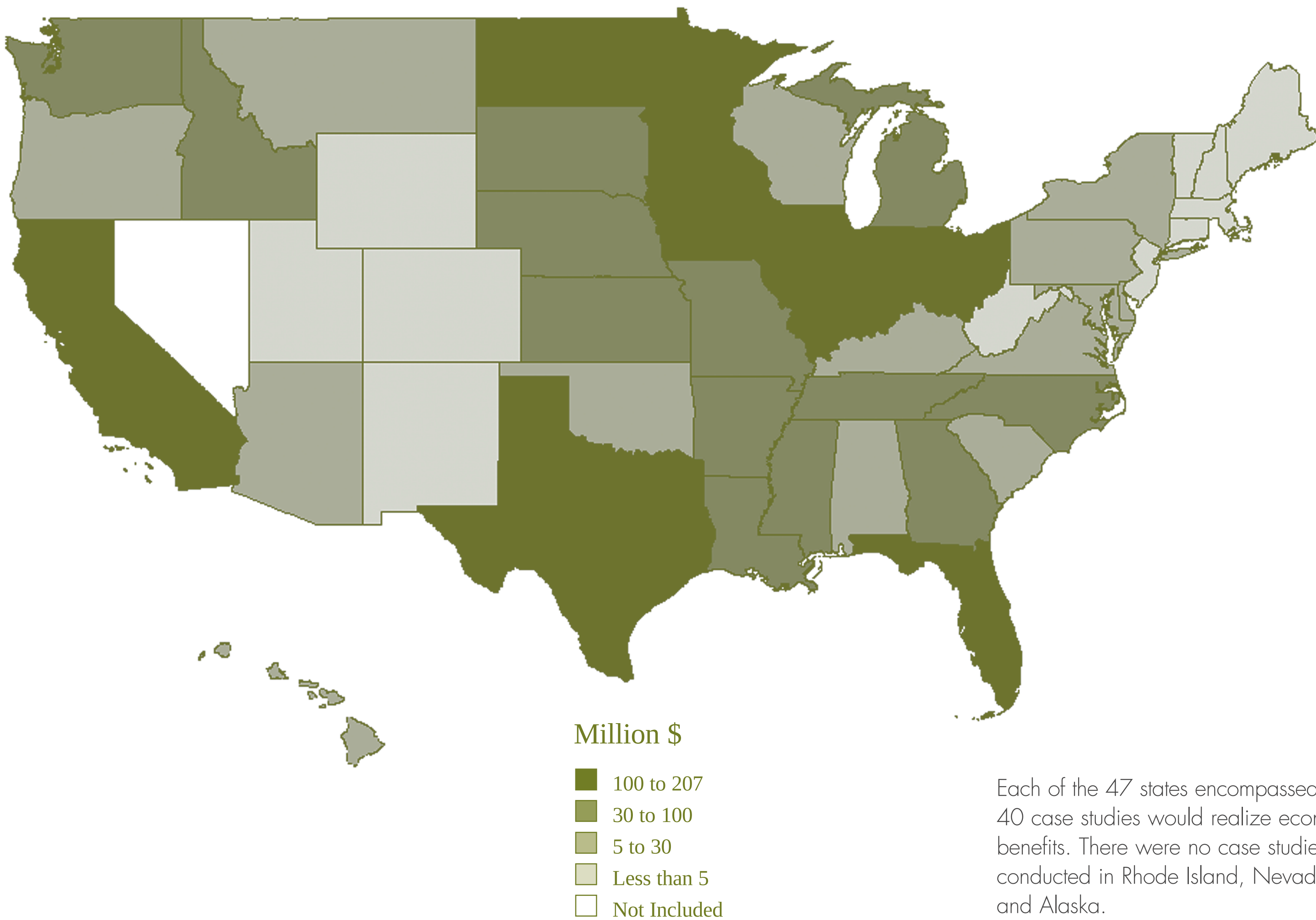
† AI refers to active ingredients.

Table 8: Total Impact of Biotech Crops by State

State	Production (per year) Volume (000 lbs.)	Value (000$)	Costs (000$)	Total Net Value (000$/yr.)	Pesticide Use (lbs. AI/yr.)†
Alabama	10,381	5,120	-7,155	12,275	-736,521
Arkansas	31,689	8,583	-74,670	83,253	-2,908,744
Arizona	19,512	10,222	-1,024	11,246	-64,404
California	29,209	28,076	-178,454	206,530	-65,830,119
Colorado	46,144	1,647	-2,571	4,218	-328,980
Connecticut	728	26	-100	126	-4,687
Delaware	10,640	381	-4,860	5,241	-199,930
Florida	1,586,486	103,590	-63,953	167,543	-2,040,540
Georgia	85,069	28,652	-12,375	41,027	-1,929,948
Hawaii	53,000	17,000	-2,100	19,100	-1,427,790
Iowa	628,992	22,464	-161,233	183,697	-8,302,180
Idaho	1,099,690	55,587	-25,152	80,739	-18,853,784
Illinois	241,248	8,616	-126,014	134,630	-8,898,870
Indiana	85,792	3,064	-146,660	149,724	-8,322,368
Kansas	567,456	20,960	-31,788	52,748	-1,878,760
Kentucky	41,216	1,471	-13,179	14,650	-559,400
Louisiana	1,480,783	21,385	-75,984	97,369	-4,741,754
Massachusetts	2,280	410	-198	608	-5,906
Maryland	39,920	1,490	-12,719	14,209	-342,995
Maine	0	0	-103	103	-1,126
Michigan	61,752	3,735	-31,964	35,699	-827,940
Minnesota	578,848	23,517	-132,723	156,240	-5,145,888
Missouri	209,909	10,121	-71,787	81,908	-3,485,579
Mississippi	212,930	39,513	-46,664	86,177	-2,559,255
Montana	312,000	15,600	-4,900	20,500	37,000
North Carolina	21,680	7,999	-34,804	42,803	-1,881,958
North Dakota	2,410,920	150,989	-33,801	184,790	-86,732
Nebraska	487,592	17,414	-36,245	53,659	-3,020,542
New Hampshire	0	0	-43	43	-466
New Jersey	6,264	288	-1,537	1,825	-58,770
New Mexico	10,397	1,841	127	1,714	-18,906
New York	35,200	3,651	-3,821	7,471	-516,074
Ohio	300,536	11,163	-93,170	104,333	-4,379,922
Oklahoma	41,259	8,689	672	8,017	143,605
Oregon	431,547	24,254	-3,815	28,069	-8,035,040
Pennsylvania	109,288	19,696	-9,509	29,205	-591,598
South Carolina	16,171	4,642	-12,995	17,638	-133,216
South Dakota	518,480	22,560	-51,667	74,227	291,444
Tennessee	54,768	14,378	-23,564	37,942	-932,898
Texas	1,427,348	94,367	-14,820	109,187	-761,132
Utah	0	0	-70	70	-7,000
Virginia	13,052	1,934	-3,644	5,578	145,020
Vermont	560	21	-83	104	-5,210
Washington	1,045,323	70,154	-5,969	76,123	-2,999,276
Wisconsin	125,200	4,301	-21,995	26,296	-512,106
West Virginia	4,168	306	-138	444	8,106
Wyoming	0	0	-2,830	2,830	47,000

† AI refers to active ingredients.

Potential Benefits of Biotechnology Adoption by State



Each of the 47 states encompassed by the 40 case studies would realize economic benefits. There were no case studies conducted in Rhode Island, Nevada and Alaska.

Comparison With Other Studies

Government agencies, university scientists and advocacy groups have conducted other analyses. These studies primarily considered the impacts of currently commercialized traits: insect resistant field corn and cotton, and herbicide tolerant soybeans. The current study extends the analysis to estimate the benefits of other crops that are already commercialized, including herbicide tolerant corn, cotton and canola, and virus resistant squash and papaya, which have not been widely considered. In addition, this study is the first to project the benefits of many biotech crops that are under development.

Many of the earlier studies, as discussed in the full report, have been limited by the time frame considered, examining the impact of the technology in the first few years of commercialization. These analyses are early assessments of the technology, when growers were still becoming familiar with the technology and adoption was relatively low. Furthermore, some analyses have considered years in which pest infestations, and consequent benefits, were much lower than normal. Finally, many studies, including previous reports by authors of this study, have relied on comparisons to a baseline year before the introduction of the biotech varieties. However, since the introduction of these crops in the mid-1990s, there are new conventional alternatives available to growers. The current study refines these methodologies by bringing the analysis up to date with current data, considering the range of impacts across differing levels of pest pressure, and assessing the technology in light of currently available alternatives.

Conclusion

The examination of 40 case studies of biotechnology applied to pest management in agriculture demonstrates that biotechnology is having and can continue to have significant impact on improved yields, reduced grower costs and pesticide reduction.

If growers adopt all of the cultivars examined by NCFAP, the total net economic impact would be $2.5 billion per year, an annual increase in production of 14 billion pounds and a pesticide reduction of 163 million pounds per year.

Eight currently adopted cultivars are having a significant impact, primarily in major commodity crops. Combined, they are reducing pesticide use by 46 million pounds per year, increasing yield by 4 billion pounds per year and providing a net economic impact of $1.5 billion per year.

Thirty-two additional cultivars, either not yet fully developed or not yet adopted, will extend similar impact to other crops. Their potential is as follows: increased production of 10 billion pounds per year, net economic impact of $1 billion per year and an annual pesticide-use reduction of 117 million pounds.

Current cultivars primarily address weed control and insect control. The next wave of cultivars will greatly extend biotechnology into the control and prevention of crop diseases.

Every cultivar examined for this report has potential to significantly impact pest control, either through pesticide reduction, increased yield or reduced cost. Each cultivar provides value equal to or greater than the pest-control practice it would replace.

Every state examined for this report would realize economic benefits from the adoption of one or more cultivars.

Notes

National Center for Food & Agricultural Policy
1616 P Street, NW, Washington, D.C. 20036 Phone: (202) 328-5048 Fax: (202) 328-5133 E-mail: ncfap@ncfap.org
www.ncfap.org