THE POTENTIAL FOR BIOTECHNOLOGY TO IMPROVE CROP PEST MANAGEMENT IN THE US

– 30 Crop Study –

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Introduction

With the use of modern genetic transformation techniques, such as microprojectile bombardment of plant tissue, scientists have been inserting genetic material into plant species from other biological species, such as bacteria. The resulting transgenic plant cultivars express proteins that normally are not part of the plant's genetic makeup. Several transgenic cultivars have been commercialized in the U.S. and have been widely planted after regulatory review of numerous health and safety studies.

The genetically engineered crop cultivars that have been planted widely in the U.S. deliver pest management benefits. They have been genetically engineered for one of three pest management purposes:

- Herbicide tolerant engineered cultivars produce a protein from a soil bacterium that allows the use of an herbicide that kills conventional cultivars
- Insecticidal engineered cultivars produce a protein from a soil bacterium (*Bt*) that is toxic to insects
- Virus resistant engineered cultivars contain viral genes that confer immunity

Genetically engineered cultivars that have been planted on a substantial portion of U.S. acreage include herbicide tolerant soybeans, canola and cotton; insecticidal field corn and cotton; and virus resistant squash and papaya. Farmers have planted these cultivars because they provide greater yields and/or reductions in cost and consequently improve financial bottom lines. One of the more dramatic cases is that of virus resistant papaya cultivars, which are generally credited with saving the Hawaiian papaya industry.

Problem Statement

As a result of the controversy over crop biotechnology, there has been a recent slowdown in the adoption of new genetically engineered crops in the U.S., even though these cultivars would provide substantial economic benefits to farmers. Genetically engineered sugarbeets, potatoes and sweet corn cultivars have been approved for use and have been commercialized, but not adopted. Seed companies have promoted the benefits of planting these genetically engineered cultivars, and yet hardly any acreage of these crops is being planted with them because major processors, packers and food companies (such as McDonald's) have told growers that they are not willing to purchase the genetically engineered product.

Several genetically engineered pest management cultivars are nearing full regulatory approval and commercialization in the U.S. These include new insecticidal corn and cotton cultivars for control of additional insect pests, insecticidal soybeans, and herbicide tolerant wheat. Numerous genetic engineering projects for improved pest management are in the research stage at universities and in federal laboratories. Several of these ongoing projects are also supported by local commodity organizations.

No compilation exists that describes the numerous genetic engineering projects in the research and commercialization pipelines, and the potential aggregate benefits they offer have never been estimated. Nor have estimates been made of the benefits forfeited by farmers not planting approved genetically engineered crops due to the controversy surrounding them. Consequently, the ongoing debate regarding transgenic crops is being conducted without a full understanding of the overall potential of crop biotechnology to improve pest management in the U.S.

NCFAP Study

The National Center for Food and Agricultural Policy (NCFAP) is preparing a report that quantifies the potential impacts of crop biotechnology in improving pest management in the U.S. The NCFAP covers 30 crops:

- Field Corn
- Cotton
- Papaya
- Sugarcane
- Pineapple
- Lettuce
- Peas
- Peaches
- Sweet Corn
- Soybeans
- Potatoes
- Wheat
- Citrus
- Grapes
- Eggplant
- Alfalfa
- Peanuts
- Canola
- Rice
- Barley
- Sunflowers
- Apples
- Broccoli
- Tomatoes
- Squash
- Sugarbeets
- Raspberries
- Oats
- Strawberries
- Pears

For some crops NCFAP has identified two or more genetic engineering projects for pest management purposes, in which case an individual study for each project will be prepared. As a result, NCFAP is preparing 44 case studies for the 30 crops. Table 1 lists the crops and identifies the case studies being prepared for each.

For genetically engineered cultivars that are currently in the research and/or commercialization stages, the NCFAP report projects and quantifies potential benefits that would likely result from their planting. Realized aggregate benefits for the year 2000 are estimated for plantings of the already commercialized, genetically engineered canola, soybeans, squash, papaya, cotton and field corn.

Methodology

NCFAP is conducting a literature search and is contacting the researchers and commercial interests involved in the development of the transgenic cultivars. NCFAP's report on each crop includes sections on the biology of target pests; historical efforts to control the pests; documentation of yield losses due to the pests; extent, cost and effectiveness of pesticides presently used to control the pests; research into alternative methods of controlling the pests; description of the genetic transformation of the crop; and documentation of the effectiveness of the transgenic crop in controlling the target pests. Since many of the transgenic cultivars included in the study are still in early research stages, it is sometimes necessary to make assumptions about their effectiveness and costs based on similar commercialized products. NCFAP is projecting the likely potential adoption of each genetically engineered crop by state based on the presence of the target pests and the likely net return that growers would achieve in each state through adoption. Projected increases in per acre crop yield value are being compared to projected changes in per acre cost of pest control. It is assumed that growers will plant the transgenic cultivars in regions where the per acre increased value of the crop yield is greater than increased pest control costs. In some cases, yield stays the same or increases while pest control costs decrease.

In addition to estimating the aggregate impacts on production and net returns, NCFAP is estimating the aggregate impacts of planting genetically engineered cultivars on pesticide use amounts, and tillage.

Output

NCFAP is preparing a comprehensive report that includes each of the 44 case studies. Each case study is approximately 10 pages in length, including text, references, tables and figures. In addition, NCFAP is preparing summary tables that include all of the estimates of changes in production amounts and value, changes in costs of production and pesticide use amounts. NCFAP is also preparing one page summary sheets for each case study. Eight of these summary sheets are attached. The complete NCFAP report and full set of summary sheets will be released in September, 2001.

Table 1: Biotechnology Pest Management Case Studies for 30 Crops

Crop/Case Study

1. Papaya
   A. Viral Resistant
2. Squash
   A. Viral Resistant
3. Peanut
   A. Viral Resistant
   B. Insect Resistant
4. Tomato
   A. Viral Resistant
   B. Herbicide Tolerant
5. Lettuce
   A. Herbicide Tolerant
6. Strawberry
   A. Herbicide Tolerant
7. Pineapple
   A. Nematode Resistant
8. Broccoli
   A. Insect Resistant
9. Citrus
   A. Viral Resistant
   B. Bacterial Resistant
10. Sweet Corn
    A. Insect Resistant
    B. Herbicide Tolerant
11. Peach/Nectarine/Plum/Apricot
    A. Viral Resistant
12. Raspberry
    A. Viral Resistant
13. Potato
    A. Viral Resistant/Insect Resistant
    B. Fungal Resistant
    C. Herbicide Tolerant
14. Sugarbeet
    A. Herbicide Tolerant
15. Grape
    A. Bacterial Resistant

Crop/Case Study

16. Apple
    A. Bacterial Resistant
17. Sunflower
    A. Fungal Resistant
18. Soybean
    A. Herbicide Tolerant
    B. Insect Resistant
19. Canola
    A. Herbicide Tolerant
20. Rice
    A. Herbicide Tolerant
21. Field Corn
    A. Insect Resistant (1)
    B. Insect Resistant (2)
    C. Insect Resistant (3)
    D. Herbicide Tolerant
22. Cotton
    A. Insect Resistant (1)
    B. Insect Resistant (2)
    C. Herbicide Tolerant
23. Alfalfa
    A. Herbicide Tolerant
24. Barley
    A. Disease Resistant
25. Wheat
    A. Herbicide Tolerant
    B. Disease Resistant
26. Eggplant
    A. Insect Resistant
27. Pears
    A. Insect Resistant
28. Peas
    A. Herbicide Tolerant
29. Oats
    A. Disease Resistant
30. Sugarcane
    A. Herbicide Tolerant
    B. Disease Resistant

BIOTECHNOLOGY CASE STUDY SUMMARY

1.A. Virus Resistant Papaya: Hawaii

Papaya ringspot virus (PRSV) is the most important disease of papayas worldwide. It can be lethal to seedlings, and older plants infected with PRSV suffer from reduced growth and reduced fruit set. Fruit that is produced is of poor quality, marred by circular dark green marks and degraded flavor. The virus is transmitted by aphids and affects a number of plants, many of which harbor the virus without showing symptoms. It takes one PRSV-carrying aphid a short time of feeding to infect a papaya plant. Consequently, insecticide applications are unsuccessful in managing PRSV because they do not eradicate the aphid or the virus. There is no cure for a PRSV-infected papaya, and no natural PRSV resistance has been found in the papaya genome. To manage the spread of PRSV, growers are advised to remove and destroy all plants suspected of having PRSV and all susceptible plants within the surrounding area.

In Hawaii, the only state in the U.S. to produce papaya, PRSV has limited 95% of the once expansive industry to a single region in the state, the Puna district on the island of Hawaii. In 1992, however, PRSV was detected in Puna papaya. By 1994, half the papaya acreage in Puna was infected with PRSV. Within five years, the entire district was infected with PRSV and Hawaii's papaya production was almost halved.

Researchers at the University of Hawaii and at Cornell University have inserted a PRSV viral coat protein gene into an elite papaya cultivar. Through traditional crossbreeding of the transgenic papaya with other elite cultivars, two elite papaya varieties with pathogen-derived resistance to PRSV have been developed, one red-fleshed and one yellow-fleshed. Resistance to PRSV, and fruit and horticultural qualities were tested in field trials in the early 1990's. With regulatory approval granted in 1997 and licensing agreements settled in 1998, the virus resistant seed was distributed free of charge to Hawaiian papaya growers in May of 1998. By 2000, approximately 53% of papaya acreage in Hawaii was planted with one of the PRSV-resistant cultivars and statewide production had increased by 33%. Transgenic papaya is being credited with saving the Hawaiian papaya industry.

Potential Impacts of Virus Resistant Transgenic Papaya: Hawaii
Prevent the loss of Hawaiian papaya industry, with 53 million pounds annual production and $17 million annual value.

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BIOTECHNOLOGY CASE STUDY SUMMARY

4.A. Virus Resistant Tomatoes: Florida

Whitefly transmitted geminiviruses have had major economic impacts on U.S. tomato production in the last decade, particularly in Florida. This is due to the introduction in 1987 of a new whitefly that feeds on tomatoes, followed by the development of two geminiviruses in 1989 and 1997 that infect tomatoes and that are spread by the new whitefly. Reduction in crop value of 1990-91 Florida tomatoes due to the first geminivirus, tomato mosaic virus (ToMoV), was conservatively estimated to be 20%, or $140 million. The second geminivirus, tomato yellow leaf curl virus (TYLCV), may reduce a tomato plant's production severely, or even eliminate it, depending on when in the season the plant is infected.

There are no commercially available cultivars with immunity or significant tolerance to geminiviruses. Geminivirus management therefore has been based on whitefly management. Multiple applications of various insecticides were used, with inconsistent results, until 1994 and the introduction of imidacloprid, a systemic insecticide with efficacy against all whitefly lifestages. Currently, growers use one soil application of imidacloprid at planting, followed eight weeks later by a rotation of foliar insecticides. Whitefly treatment programs are expensive, adding approximately $273/acre to production costs, but losses due to ToMoV and TYLCV remain low as a result.

Research on transgenic, virus resistant tomatoes began at the University of Florida in the early 1990's. Studies on pathogen-derived resistance revealed that tomato plants transformed with a mutated copy of a symptom-inducing viral gene did not develop symptoms even when infected with the virus. This procedure for pathogen-derived resistance has been used to produce tomato lines with resistance to ToMoV and lines with resistance to TYLCV. Field tests show that in the absence of virus pressure yields of transformed varieties are equal to yields of untransformed varieties. In the presence of virus pressure, transgenic plants remain symptom free with yields 1.7 times greater than the non-transformed commercial hybrid.

Potential Impacts of Virus Resistant Transgenic Tomatoes: Florida

Change in Production:	none
Change in Pesticide Use:	88,000 pound/yr reduction in insecticides (88% reduction)
Change in Production Costs:	$10.7 million/yr net savings in insect control

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BIOTECHNOLOGY CASE STUDY SUMMARY

4.B. Herbicide Tolerant Tomatoes: California

Tomato prices contracted at the beginning of the season between growers and processors have declined steadily since 1998, in part because of a surplus in processing tomatoes. As a result, growers look for ways either to increase yields or to reduce costs as a way of maintaining or improving their income. Weed control costs are a major part of the operating costs for processing tomatoes.

Ninety percent of processing tomatoes produced in the U.S. come from California. Ninety nine percent of California's tomatoes are treated with herbicides for weed control. Pigweed, lambsquarters and barnyardgrass are prevalent weed species in California processing tomato fields, and they are controlled adequately with available herbicides such as napropamide, pebulate, trifluralin, and the soil fumigant metam sodium.

Some weed species found on California processing tomato acreage, however, are not adequately controlled by registered herbicides. Nightshade species and nutsedge are widespread and competitive weeds in California processing tomatoes, causing substantial yield reductions, and bindweed interferes with mechanical harvests. Handweeding and cultivation are used on all of California's tomato acreage to manage these problem weeds not controlled by herbicides. However, the control provided by handweeding and cultivation is not long lasting. In addition, hand crews may accidentally remove significant numbers of tomato plants, especially when targeting nightshade species which are very similar in appearance to tomato seedlings.

Tomato plants have been transformed via microprojectile bombardment with a gene that makes them tolerant to direct broadcast application of glufosinate, a nonselective herbicide with efficacy against a wide range of grass and broadleaf weeds. The gene originates from a bacterium and codes for an enzyme called phosphinothricin acetyl transferase (PAT). Transformed tomato plants were backcrossed with elite cultivars and the resulting hybrids have been field tested. The genetically engineered tomatoes show tolerance to glufosinate at all developmental stages, allowing its use for control of problem weeds.

Potential Impacts of Herbicide Tolerant Transgenic Tomatoes: California

Change in Production:	none
Change in Pesticide Use:	4.2 million lb/yr net reduction in pesticide use due to replacement of metam sodium with glufosinate
Change in Production Costs:	$30 million/yr net savings in handweeding, cultivation and pesticide costs

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BIOTECHNOLOGY CASE STUDY SUMMARY

9.A. Virus Resistant Citrus: Texas

Texas citrus production is concentrated in the Lower Rio Grande Valley (LRGV). Approximately 98% of citrus grown in Texas' LRGV is planted on sour orange rootstock because sour orange is tolerant of the adverse soil conditions of that area. Sour orange rootstock, however, is susceptible to citrus tristeza virus (CTV), including the severe strains that cause quick decline. Citrus tristeza virus is the most devastating disease of citrus worldwide. There is no remedy for an infected tree other than to remove it. Both grapefruit and sweet orange cultivars are susceptible to CTV if planted on sour orange rootstock. Seventy percent of Texas citrus production is grapefruit.

Severe strains of CTV are present in Texas already, but not in areas of commercial citrus production. Rather they are in residential areas in the eastern part of the state, where soil conditions allow rootstock other than sour orange to be planted. These CTV-infected dooryard trees do not show symptoms, but they do serve as reservoirs for further spread of the disease. Spread of CTV has not reached commercial citrus production in the LRGV largely because an efficient vector of CTV is not yet present in Texas.

The brown citrus aphid is the most efficient vector of CTV, particularly severe strains. Currently the brown citrus aphid is found in Mexico and Florida, and is expected to reach Texas. When the brown citrus aphid arrives in Texas, it will likely move severe strains of CTV from symptomless dooryard trees in the east to susceptible commercial orchards in the LRGV, potentially destroying the Texas citrus industry. Insecticide use against brown citrus aphid populations will not help control CTV spread because they do not completely eradicate aphid populations.

Planting citrus varieties resistant to CTV is the key to preventing virus infection. Natural CTV resistance exists in citrus relatives, but cannot be incorporated into commercial citrus varieties through traditional breeding techniques without also incorporating horticultural qualities that make the resulting fruit inedible. Researchers at Texas A&M University are using biotechnology to insert CTV coat protein genes into commercial citrus varieties to produce pathogen-derived resistance. In 2000, transformed grapefruit shoots grafted onto sour orange rootstock were planted in a field trial, and preliminary data indicate they have CTV resistance. The field trials are expected to bear fruit in a few years, at which point fruit quality will be tested. With development of CTV resistant citrus fruit cultivars, Texas growers will be able to continue using sour orange rootstock in the presence of brown citrus aphid without risking devastation from severe strains of CTV.

Potential Impacts of Virus Resistant Transgenic Citrus: Texas

Prevent the loss of Texas's citrus industry, with 622 million pounds annual production and $48 million annual value.

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BIOTECHNOLOGY CASE STUDY SUMMARY

10.A. Insect Resistant Sweet Corn: Florida

Florida ranks number one in the U.S. for production and value of fresh market sweet corn. Two of the most important insect pests of Florida sweet corn are fall armyworm and corn earworm. Corn earworm initially feeds on the silk, then tunnels downward, leaving a trail of damage and waste that often ruins the entire ear. Fall armyworm causes similar damage, though its larvae may also enter ears by burrowing through husks on the side. Other economically significant insect pests in Florida sweet corn include the corn silk fly, which is a major pest only in the southernmost production areas of the state, and the lesser cornstalk borer, which appears sporadically in southern Florida.

Fall armyworm is considered the more serious pest of sweet corn in Florida. Fall armyworm survives winters in the warm, humid conditions of south Florida and is therefore a threat to the state's sweet corn throughout the growing season. The internal feeding habits of fall armyworm larvae make them only susceptible to pesticide applications during their migration down the corn stalk to newly developing, pre-silk ears. During this window of treatment opportunity, some sweet corn growers apply insecticides as much as twice daily in order to prevent fall armyworm larvae from reaching and feeding on young ears. Once fall armyworm larvae enter ears to feed, they are virtually impervious to insecticide sprays. Typically, insecticide applications then are continued throughout silking to control fall armyworm larvae that survived pre-silk applications and have not yet entered the plant. In total, an acre of sweet corn in Florida will be treated with insecticides an average of 12 times per season.

A commercialized field corn variety transformed with a *Bt* gene was bred with sweet corn cultivars to produce transgenic *Bt* sweet corn. Novartis (now Syngenta) Seeds registered the *Bt* sweet corn cultivars with EPA in 1998 and marketed them under the trade name Attribute. In field trials, the season-long insect protection of *Bt* sweet corn cultivars consistently produced more marketable yield than non-*Bt* cultivars, and required between 42% and 84% fewer insecticide applications. Because *Bt* sweet corn does not provide protection against the corn silk fly, its adoption in Florida is not expected to eliminate insecticide applications altogether, but rather is expected to drop average per season applications from 12 to 2 on 80% of the acreage. Despite the potential beneficial impacts of planting *Bt* sweet corn, Florida sweet corn growers are not planting the transgenic cultivars due to concerns regarding potential lost sales.

Potential Impacts of Insect Resistant Transgenic Sweet Corn: Florida

Change in Production:	22 million lbs/yr increase
Change in Production Value:	$3.9 million/yr increase
Change in Insecticide Use:	112,000 lbs/yr reduction (79% reduction)
Change in Production Costs:	$1.3 million net savings in insect control

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BIOTECHNOLOGY CASE STUDY SUMMARY

12.A. Virus Resistant Raspberry: Oregon/Washington

In the 1980's, the most commonly planted raspberry cultivar in the Pacific Northwest changed from Willamette to Meeker. Meeker is higher yielding and the fruit it produces is larger, sweeter, firmer and more likely to remain whole even when mechanically harvested. Meeker plants, however, are susceptible to raspberry bushy dwarf virus (RBDV).

Raspberry plants infected with RBDV are neither bushy nor dwarfed. The virus reduces plant productivity and reduces fruit quality, making it crumbly. Fruit produced by RBDV-infected plants is unsalable in the fresh and individually quick frozen (IQF) markets and will only sell in the juice or jam market. High quality, whole fruit sold fresh or processed as IQF berries is worth approximately \$0.75 - \$1.25 per pound, whereas juice or jam grade fruit sells for \$0.25 - \$0.28 per pound. In 1996, 84% of the raspberry fields in northern Washington were infected with RBDV.

There is no treatment for RBDV, which is spread in the pollen of infected plants, so growers remove infected plants and replant with virus-free plants. Because of RBDV, the productive life of the average raspberry planting has been reduced from approximately 15 years to approximately 5 years. The process of replanting a raspberry field includes removing old plants and their trellises, fumigating the soil with an average of 200 lbs/acre active ingredient (ai) methyl bromide and 60 lbs/acre ai chloropicrin, replanting and retrellising. The cost for this, in addition to revenue lost to RBDV symptoms and production lost during maturation of new plantings, is an estimated \$1,386 per acre/year.

A collaborative effort in Oregon between USDA-ARS researchers and Agritope, Inc. has resulted in the successful transformation of raspberry plants with RBDV resistant properties. Three different pathogen-derived mechanisms for RBDV resistance are being tested in field trials. Preliminary data from the first year of field trials indicate that 80% of the transgenic raspberry plants remained virus free. Fruit quality will be assessed in 2001 when the transgenic plants are expected to begin producing raspberries.

Potential Impacts of Virus Resistant Transgenic Raspberries: Oregon and Washington

Change in Production:	prevent loss of 10 million lbs/yr
Change in Production Value:	\$11.2 million/yr in additional and higher value production
Change in Production Costs	\$2.5 million/yr savings in replanting costs
Change in Pesticide Use:	371,000 lb/yr reduction in fumigants (50% reduction)

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BIOTECHNOLOGY CASE STUDY SUMMARY

18.A. Herbicide Tolerant Soybeans: 30 States

More than 30 plant species infest soybean fields in the major soybean producing areas of the U.S. Natural weed populations in most fields are high enough to cause yield losses of 50-90% if left uncontrolled. By the early 1990's there were at least 70 registrations for individual herbicides or prepackaged mixtures for weed control in soybeans. As a result, most weeds in soybeans were adequately controlled with the herbicides available in the early 1990's.

Roundup Ready soybean varieties were introduced for planting by U.S. farmers in 1996, allowing treatment of a growing soybean crop with glyphosate (Roundup). Through genetic engineering, scientists at Monsanto inserted genetic material from a soil bacterium into soybean plants, rendering them tolerant to direct applications of glyphosate. Roundup is a highly effective broad spectrum herbicide that controls most of the commonly occurring weed species in soybean fields. U.S. growers rapidly adopted the planting of Roundup Ready soybeans with the associated use of glyphosate. In 2000, 54% of the nation's soybean acreage was planted with Roundup Ready varieties, increasing to 63% in 2001. U.S. soybean growers switched away from most of the herbicides that had been previously used. The primary reason growers have adopted Roundup Ready weed control programs is the simplicity of a weed control program that relies on one herbicide to control a broad spectrum of weeds. Previously, growers would often apply three or more active ingredients to the same acre.

One key impact of the introduction of Roundup Ready soybeans has been a major expansion in soybean acreage in states with tough, hard to control weed problems, including New York, South Dakota, and Kansas. The use of Roundup made it possible to control these problem weed species at a reasonable cost.

Soybean growers continue to use the Roundup Ready system because it remains much more economical than alternative weed control programs. If Roundup Ready soybeans were not available, growers would likely substitute combinations of herbicides which would increase production costs. For example, it has been estimated that the likely alternative weed control programs would increase weed control costs by $12/acre in Illinois, $23/acre in New York, $33/acre in South Dakota, and $14/acre in Mississippi.

Estimated Benefits of Herbicide Tolerant Soybeans: 30 States

If U.S. growers no longer planted the genetically engineered herbicide tolerant soybean cultivars, they would likely substitute alternative herbicides which would increase soybean production costs by $735 million/year ($15/A increase on 49 million acres).

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BIOTECHNOLOGY CASE STUDY SUMMARY

22.A. Insect Resistant Cotton (1): U.S.

Bt cotton varieties were introduced in 1996, providing control of three major cotton insect pests: tobacco budworm, cotton bollworm and pink bollworm. These varieties offer an alternative to conventional insect spray programs. Tobacco budworm infestations were particularly heavy in 1995, causing severe yield loss in some areas. The worst damage was sustained by Alabama growers, who on average experienced a 29% yield loss due to bollworm/budworm. These losses were attributed to the ineffectiveness of pyrethroid insecticides against budworm, due to the development of resistant populations in some states.

The adoption of *Bt* varieties was extremely rapid in some areas. After the year of very high budworm populations and damage in 1995, growers in Alabama adopted the new technology at an extremely rapid rate, planting over 60% of total acreage to *Bt* varieties in 1996. In 2000, 65% of cotton acreage in Alabama was in *Bt* varieties. Florida and Mississippi also adopted the technology on over 30% of cotton acreage in 1996. By 2000, four states had adoption rates of over 75%: Florida, Louisiana, Mississippi, and Tennessee.

The impacts of the adoption of *Bt* cotton varieties include a reduction in yield losses due to *Bt* target pests, reductions in insecticide use, and cost savings. Yield losses due to *Bt* target pests have declined in 12 of 16 reporting states.

Comparing USDA pesticide use data for six states for 1995 to 1998 and 1999 shows a dramatic reduction in the use of insecticides used to control cotton bollworm, tobacco budworm, and pink bollworm. The use of cotton insecticides for *Bt* target pests declined by over 2 million pounds between 1995, and 1998, and by 2.7 million pounds by 1999.

Several surveys have found that growers are achieving higher yields and attaining higher profits by planting *Bt* varieties, due to better pest control and decreased insect control costs. The average increase in net income in 1999, comparing *Bt* to conventional varieties, was $20.81/acre, taking into account the technology fee. On average, per acre insect control costs were $14.28 higher. This increased cost was outweighed by a yield increase of 9%, or 55 lbs/acre. These yield and revenue impacts, if realized over all 4.67 million acres of *Bt* cotton in 1999, would indicate a $99 million increase in revenues and 260 million lbs increased cotton production.

Estimated Impacts of Insect Resistant Cotton (1): U.S.

Change in Production	260 million lbs/yr increase in production
Change in Pesticide Use	2.7 million lbs/yr decrease in insecticides
Change in Net Revenue	$99 million/yr increase in net revenue

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Full Report: *The Potential for Biotechnology to Improve Crop Pest Management in the U.S.: 30 Crop Study* by Leonard P. Gianessi and Cressida S. Silvers, National Center for Food and Agricultural Policy, September 2001.

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