E. Benefits Assessment

1. Introduction

EPA conducted benefits assessment for the *Bt* plant-incorporated protectants prior to their registrations. For *Bt* corn(field corn) products, the major private benefits predicted were an increase in yield due to a reduction in insect damage and for *Bt* cotton, *Bt* potatoes, and *Bt* sweet corn the major benefits predicted were a reduction in the use of chemical insecticides yielding private benefits for the farmer and environmental benefits for society. The information available to the Agency confirms that these general predictions were accurate, although environmental benefits were difficult to quantify.

The analyses estimate benefits for the past three years of *Bt* plant-incorporated protectants and it is expected that benefits will continue around the level of 2000 for at least the next five years. If adoption of Bt plant-incorporated protectants in cotton continues to expand worldwide, the benefits should be shifted largely to consumers in the form of lower prices for corn and cotton products. It is not clear what will happen with *Bt* sweet corn and *Bt* potato benefits. It is expected that the registrants of the *Bt* products will expand the range of varieties in which they are incorporated in. This should help overcome market acceptance questions.

Most farmers growing field corn in the United States do not use chemical insecticides to control the target pests and therefore, the potential benefits were anticipated to be yield increases rather than reduced pesticide costs or reduced pesticide use. A small percent (even 1 or 2%) reduction in chemical pesticide use can be significant, since it is across the 15 to 20 million acres of corn which have adopted *Bt* corn in the United States. Farmers growing *Bt* corn who were not using chemical insecticides have seen increased yields in areas where infestations of European corn borers (ECB), Southwestern corn borers (SCB), and corn earworm (CEW) are common or reach moderate to severe levels. The number of insecticide applications to control target pests for cotton have also decreased, dramatically in some reported situations. The adoption of *Bt* potatoes and *Bt* sweet corn is far less than that in the other crops. A variety of reasons are likely to be responsible for *Bt* potatoes including the introduction of a new, highly effective chemical insecticide for the same target pest (the Colorado potato beetle). It is not clear why *Bt* sweet corn has not been widely adopted.

Although farmers pay a premium to use *Bt* plant-incorporated protectant products, farmers anticipate benefits that exceed the premium, assuming profit maximization. Actual benefits at the end of the growing season can be less than anticipated benefits, such as when corn growers face unexpectedly low ECB pest pressures, or when corn commodity prices are unexpectedly low. Another example is when cotton growers face unexpected high pest pressure from a secondary pest (such as tarnish plant bug which is not controlled by Cry proteins) and the savings on reduced chemical use never materializes.

Farmers must make a decision on whether to plant *Bt* crops at the beginning of the season before they know the magnitude of pest problems that they will face during that growing season. This implies farmers probably do not plant the most profitable level of *Bt* crops given the technology fee charged. Farmers who recognize the problems corn borer cause and who regularly have significant corn borer damage may plant for the insurance value. We believe that, financially, this makes sense for field corn. Cotton represents a different situation. The practice has long been to plant the crop early with a high yielding short season variety of cotton so it can mature prior to the worst period of insect pressure late in the growing season. *Bt* cotton, enables farmers to continue this practice and presents favorable odds to reduce the cost of conventional pesticide use and reduce yield losses due to the bollworm/budworm insect complex. That is, the probability of financial loss from not planting *Bt* cotton may outweigh the cost of the additional technology fee. The logic of this approach depends on the historical profitability of the crop and pest pressures in the area and possibly the field.

2. Review Methodology

a. Scope of Review

Although registrations were approved in 1995 for *Bt* plant-incorporated protectants in potatoes, corn, and cotton, very limited use if any, occurred that year. Usage started rather strongly in 1996 and continued to grow for field corn and cotton. Planting of *Bt* potatoes (which were first registered in 1995) never grew beyond about 50,000 acres. *Bt* sweet corn was registered in 1998 with the first significant planting in 1999. Sweet corn usage information is not available for 2000. It is reported that some food processors will not accepted genetically modified crops, but an evaluation of such factors on the market are beyond the scope of this work to evaluate the reason for certain plant-incorporated protectants failing to achieve significant market penetration.

This report reviews environmental and grower benefits for the most recent three years, the 1998 to 2000 period. Future benefits for the next 5 years are projected to be equal to those of average for the 1998- 2000 period. The economic analysis does not address the effects on registrant profitability, incentives for product development or the impact on government support programs, but does discuss impacts on commodity prices, shifts in benefits among producers and consumers and impacts on foreign trade.

b. Methodology

The benefits for *Bt* cotton and field corn were obtained by reviewing the public literature on the economics of *Bt* crops and estimating impacts with partial budgeting. Partial budgeting makes it easy to understand how the impacts were estimated but does not take into account distributional effects. That is, a new technology such as the *Bt* plant-incorporated protectants will increase production and/or reduce the cost of production for some producers which will have the effect of some lowering of prices. Lower prices pass some of the gains from the new technology to consumers, reduce returns to non-adopters and overestimate the net gains of adopters (price changes could be large enough that adopters also lose). *Bt* field corn effects would have been very small because average yield gains to adopters are small with essentially no reduction in operating costs (the operating costs probably go up except for those relatively few farmers who were spraying a pesticide to control the *Bt* corn target pests). The situation in cotton is too complex to determine who actually had gains and losses because of the interaction of the boll weevil economic eradication program in addition to the normal uncertainties of infestation levels of different pests. Studies have shown that *Bt* growers gained while malathion was being heavily sprayed to eliminate the boll weevil. Data were not available to make acceptably reliable estimates of yield losses on a regional basis. Therefore, we did not utilize available models to estimate regional impacts.

A demand curve simulation model was used for *Bt* potatoes and sweet corn. This model makes it more difficult for the reader to understand what was occurring but may generate estimates of higher quality than partial budgeting. *Bt* potatoes and *Bt* sweet corn are not currently being marketed by the registrants so we did not estimate benefits with partial budgeting.

We did not take into account the effects of government payment programs. Government payments represent a redistribution of income but not a benefit to society from the adoption or non-adoption of *Bt* crops. The fact that these payments exist may have impacted on the decision of some farmers to adopt *Bt* crops which may have some impact on the estimates presented.

The National Organic Program (NOP) prohibits use of genetically modified organisms in the production of organic crops. A farmer who wishes to produce organic crops, must follow the rules of the National Organic Program which essentially means only organic inputs or approved synthetic inputs can be used. If an organic farmer purchased and grew *Bt* corn, the resulting crop could not be certified organic. However, if this farmer purchased approved corn varieties and followed the other requirements for organic products under NOP, the fact that some portion of the crop was pollinated by *Bt* corn from a crop planted away from the organic crop should not adversely impact on the farmer's ability to sell the crop as organic.

Under Title 7 CFR Part 205 section 202(c) of the NOP final rule, "Any field or farm parcel from which harvested crops are intended to be sold, labeled or represented as "organic" must have distinct, defined boundaries and buffer zones to prevent the unintended application of a prohibited substance applied to adjoining land that is not under organic management." (Title 7 CFR Part 205 section 202(c)) The Supplementary information published with NOP final rule discusses this issue and follows below (80556 of the Federal Register Vol. 65, No.246, Thursday, December 21, 2000).

"Genetic" drift. Many commenters raised issues regarding drift of the products of excluded methods onto organic farms. These commenters were concerned that pollen drifting from near-by farms would contaminate crops on organic operations and that, as a result, organic farmers could lose the premium for their organic products through no fault of their own. Many commenters argued that we should use this rule to somehow shift the burden to the technology providers who market the products of excluded methods or the nonorganic farming operations that use their products. Some, for example, suggested that this regulation should require that the nonorganic operations using genetically engineered varieties plant buffer strips or take other steps to avoid drift onto organic farms. Others suggested that the regulation could provide for citizens' right to sue in cases of drift.

While we understand the concerns that commenters have raised, the kind of remedies they suggested are outside the scope of the Act and this regulation. The Act only provides for the regulation of organic operations. We cannot use this regulation to impose restrictions, such as requiring buffer strips or other measures, on operations that are not covered by the Act. Similarly, while citizens may have the ability to bring suit under other laws, the Act itself does not provide for the right to bring suit as a Federal cause of action, and we could not grant it through this regulation.

Drift has been a difficult issue for organic producers from the beginning. Organic operations have always had to worry about the potential for drift from neighboring operations, particularly drift of synthetic chemical pesticides. As the number of organic farms increases, so does the potential for conflict between organic and nonorganic operations.

It has always been the responsibility of organic operations to manage potential contact of organic products with other substances not approved for use in organic production systems, whether from the nonorganic portion of a split operation or from neighboring farms. The organic system plan must outline steps that an organic operation will take to avoid this kind of unintentional contact.

When we are considering drift issues, it is particularly important to remember that organic standards are process based. Certifying agents attest to the ability of organic operations to follow a set of production standards and practices that meet the requirements of the Act and the regulations. This regulation prohibits the use of excluded methods in organic operations. The presence of a detectable residue of a product of excluded methods alone does not necessarily constitute a violation of this regulation. As long as an organic operation has not used excluded methods and takes reasonable steps to avoid contact with the products of excluded methods as detailed in their approved organic system plan, the unintentional presence of the products of excluded methods

> *should not affect the status of an organic product or operation.*
>
> *Issues of pollen drift are also not confined to the world of organic agriculture. For example, plant breeders and seed companies must ensure genetic identity of plant varieties by minimizing any cross-pollination that might result from pollen drift. Under research conditions, small-scale field tests of genetically engineered plants incorporate various degrees of biological containment to limit the possibility of gene flow to other sexually compatible plants. Federal regulatory agencies might impose specific planting requirements to limit pollen drift in certain situations. Farmers planting nonbiotechnology-derived varieties may face similar kinds of questions if cross-pollination by biotechnology-derived varieties alters the marketability of their crop. These discussions within the broader agricultural community may lead to new approaches to addressing these issues. They are, however, outside the scope of this regulation by definition."*

Therefore, while the final rule provides significant discretion in establishing buffer zone dimensions, buffer zones do not have to be sized at distances which attempt to achieve a zero tolerance for prohibited substances. The intent of the final rule is to foster a collaborative effort between the certifying agents and their grower clients to determine an appropriate buffer zone with each party being fully cognizant of the process-based nature of the organic label claim. However, if the marketplace refused to accept organic crops containing genetic material from pollen drift, organic growers could have losses. EPA has no documentation of losses to organic growers from pollen drift and estimating the magnitude of any future losses would be speculative.

There was an article examining the implications for U.S. corn and soybean trade in the April 2000 USDA Agricultural Outlook (USDA-ERS 2000). It is noted in the article that U.S. exports of corn to the European Union(EU) have decreased because of issues related to biotech products. It is also noted that U.S. exports of soybeans to the EU have not decreased. The EU has been self sufficient corn production for a number of years but produce is not so with soybeans. From the U.S. export viewpoint, about 29% of soybean production is exported compared to about 18% of corn. About 26% of soybean exports are exported to the EU while less than 1 percent of corn exports go to the EU. The corn exports are down from about 4%. (USDA-ERS 2000) Something less than 30% of all corn contains biotech varieties and something more than 50% of all soybean contains biotech varieties. (Acreage 2001) It is noted in the Agricultural Outlook article that U.S. exports of soybeans to the EU have not decreased in spite of biotech varieties. This article goes on to illustrate that the loss of corn exports to other markets has been for reasons other than biotech.

3. *Bt* Corn Plant-Incorporated Protectants

a. Usage Estimates

There have been two grower benefit studies of *Bt* corn (field corn) (Marra, Carlson & Hubbell, 1998 and Carpenter & Gianessi, 1999) and both used essentially the same information about yield advantages due to reduced insect damage, technology fee and reductions in conventional pesticide use. As discussed above, only a very small portion of field corn acres are treated with foliar insecticides.

Field corn is the most widely grown crop in the 48 contiguous states and USDA/NASS reports acres planted for all of these states. Table E.1. contains the states which average in excess of 1 million acres planted to field corn. These 16 states account for about 90 percent of field corn acres and 93 percent of the value of field corn grown for grain. EPA estimates of planted *Bt* corn are based on registrant submissions of annual sales. Since the first registrations in 1995, planting of *Bt* corn increased to a maximum of almost 20 million acres in 1999 and decreased slightly in 2000 to 19.5 million acres. USDA estimates of acres planted to *Bt* field corn for those states covered by the corn estimating program represents about 15 million acres versus the 19.5 million acres estimated by this Agency. The states in the corn estimating program were not readily available and USDA has estimates published for 1999 and 2000. We have compared state level usage estimates from the registrants (which is claimed to be Confidential Business Information) with the USDA estimates for those states where USDA has published adoption estimates and they do not agree. The USDA estimate is based on a survey while the EPA estimate is based on sales data. Each method has its potential problems and we have no basis to prefer one over the other except that the EPA estimate covers all corn producing states. If the USDA estimates covered more states (those states listed in Table E.1 below), we would have reason to prefer the USDA estimates. The EPA estimate is used as the basis for the benefit calculation. However, we recognize that this could present an overestimate of benefits.

The Agency has recently registered an additional plant-incorporated protectant known as Cry1F which has efficacy against those pests currently controlled plus some control against the black cutworm and armyworms. This product does not provide any control of the corn rootworm which is the primary soil borne insect pest of field corn. There would have been little, if any, commercial planting of Cry1F in 2001 so we do not know actual farmer experience with this material.

Table E. 1. Acres Planted to Field Corn and Crop Value for Selected States

State	Acres planted	Crop value	Percent *Bt* corn
	1,000	1,000 dollars	
Colorado	1,253	306,309	NA
Illinois	10,867	3,007,964	14
Indiana	5,767	1,506,910	7

State	Acres planted	Crop value	Percent *Bt* corn
Iowa	12,300	3,119,481	25
Kansas	3,200	811,489	26
Kentucky	1,317	291,899	NA
Michigan	2,183	449,236	8
Minnesota	7,167	1,674,917	30
Missouri	2,667	568,464	22
Nebraska	8,633	2,109,197	26
New York	1,087	127,698	NA
Ohio	3,517	896,085	6
Pennsylvania	1,533	237,273	NA
South Dakota	3,933	649,020	37
Texas	2,150	465,761	NA
Wisconsin	3,600	718,233	14
U.S. total	79,032	18,215,745	
Percent of U.S. total in these States	90	93	89
Source: Crop Production 2000 Annual Summary, Crop Values 2000 Annual Summary, and Acreage. NA indicates USDA did not estimate *Bt* corn usage.			

b. Insect Pests

The *Bt* protein expressed by the field corn plant targets Lepidopteran insects. This protein is effective in controlling the European corn borer, the Southwestern corn borer and provides some control of the corn earworm. The European corn borer and the Southwestern corn borer are difficult to control since they bore into the corn stalk where most conventional pesticides do not provide any control. Some control can be achieved with foliar applications prior to entry into the stalk but control is not adequate since the pests usually arrive on the plant over a period two to three weeks. *Bt* corn presents a method to control virtually all of these pests. Corn borers consume plant energy and weaken the corn stalks so they are more likely to lodge (blow down) under windy conditions. Lodged stalks are difficult, if not impossible, to mechanically harvest.

The corn earworm enters the ear via the silk and feeds on the ears. Again once the insect larvae is in the ear under cover of the husk, it is difficult to control with conventional insecticides. These pests populations are not constant from year to year nationwide nor within regions. Varying population levels results in varying pest pressure, varying need for pest control and variation in the benefit a farmer will gain from controlling the pest.

The populations of these pests vary geographically and from year to year depending on environmental conditions including farming practices. This includes the past years planting of *Bt* corn. The planting of *Bt* corn on a significant portion of the corn acreage in a region probably would reduce the populations of corn borers available to survive the winter and reproduce the next year. This means that a farmer is not guaranteed to be making a wise investment with a decision to plant *Bt* corn. Some areas have historically high levels of European corn borer or the Southwestern corn borer. These include southwestern Kansas plus parts of Colorado, New Mexico, Texas and Oklahoma for the Southwestern corn borer and Iowa, Minnesota, Nebraska and South Dakota for the European Corn Borer. There is some probability that some farmers have adopted *Bt* corn when their actual damage did not warrant the additional expense. We have not been able to estimate the magnitude of this. It is reasonable to expect farmers to be examining losses in their mandated refuge acres to determine whether they should continue to plant *Bt* corn and that if damage does not reach economic thresholds, they would not plant *Bt* corn the next year.

Major states where these pests are regularly considered economic pests recommend farmers examine yields for previous years and projections for the current year (Nebraska 2001). We understand *Bt* corn is less expensive to plant than the cost of non *Bt* seed plus spraying a conventional pesticide. If a farmer were to apply two sprays, the cost would be significantly lower. It needs to be noted that something less than about 20 percent of *Bt* field corn acres were likely to have been treated with an insecticide which could target corn borers (this is discussed below).

Bt corn has been on the market for a number of years and the levels of reported damage have been down from the historical average. It is not clear if there is just an unusually long period of reduced pest pressure or if the use of *Bt* corn has resulted in a lowering of insect pressure. Either way, it is logical to expect some farmers will make a decision to reduce the portion of their corn acres planted with *Bt* corn unless the monitoring of damage in refuge acres implies continued planting of *Bt* corn is financially justified.

The addition of Cry1F *Bt* corn provides some degree of control against the black cutworm and armyworms in addition to the European corn borer and the Southwestern corn borer.

c. Potential to Replace Conventional Pesticides

Insecticide use on field corn is largely to control the soil pest complex, rather than the *Bt* corn target pests. As discussed above, those pests targeted by *Bt* corn, are difficult to control with conventional pesticides. Therefore, little conventional pesticide has been used on field corn. Five to eight percent of field corn acres may have been treated with conventional pesticides to control these pests implying that 6.3 million of those 79 million acres planted to field corn could have been treated with conventional insecticides. A look at changes from 1995 and 2000 indicates a reduction of around 3.9 million acre treatments due to all causes.

Cry1F *Bt* corn has the potential to replace conventional pesticides in areas where corn growers rotate corn with a crop such as soybeans which is not a host to the corn rootworm and their crop land is river bottomland. These farmers are unlikely to also have corn rootworm and it may be a wise economic decision to plant Cry1F *Bt* corn and would be part of the 6.3 million acres planted to field corn discussed above. Some of these farmers probably adopted other *Bt* corn products but if they have, they may have used conventional pesticides to control the black cutworm. Where there are cutworms, farmers may make the decision to plant Cry1F *Bt* corn and be able to reduce or eliminate use of conventional insecticides. While we can predict there will be some reduction, we do not have data to accurately estimate the magnitude of the potential reduction.

Assuming there was a 3.9 million acre treatment reduction due to the corn borer pests, this equates to 0.2 acre treatments per *Bt* corn acre (all 19.5 million acres). The majority of field corn growers who adopted *Bt* corn did not consider reductions in cost of conventional pesticides applied when they made the decision to plant or not plant *Bt* corn because they had not been applying conventional pesticides to control these pests.

d. Benefits for Field Corn

Field corn is grown on a average (1998-2000) of about 79 million acres with production close to 10 billion bushels having a market value of about $18 billion (Table E.2). The 1994-1996 average for acres planted was 76.6 million acres with production of 8.9 billion bushels and a market value of $24.6 billion, reflecting the fact that higher yields have been more than offset by lower prices. Other market factors may have been contributing to the change in market value.

Table E.2. 1998-2000 National Field Corn Data

Item	Unit of measure	1998	1999	2000	Average
Acres planted	1,000 acres	80,165	77,386	79,545	79,032

Acres of *Bt* corn	1,000 acres	14,500	19,800	19,500	17,933
Corn production	1,000 bushels	9,758,685	9,430,612	9,968,358	9,719,218
Yield	Bushels/acre	134.4	133.8	137.1	135.1
Value	1,000 dollars	18,922,084	17,103,991	18,621,160	18,215,745
Price per bushel	dollars	1.94	1.82	1.85	1.87

Source: Crop Production, 2000 Annual Summary, USDA/NASS
Crop Value, 2000 Annual Summary, USDA/NASS
Acres of *Bt* corn are EPA estimates obtained from industry sales reports.

Two studies estimated farmer level benefits from the adoption of *Bt* field corn. Marra, Carlson and Hubbell (1998) utilized a 4 to 8 percent increase in yield, nominal reduction in pesticide use and a technology fee of about $11 per acre. They discussed economic thresholds for adoption of *Bt* corn but did not estimate overall benefits. Gianessi and Carpenter (1999) estimated benefits for 1997 through 1999. They estimated farmers had significant gains in 1997 and a net loss in 1998 and 1999 because yield gains went from 12 bushels in 1998 to 4.2 in 1998 and 3.3 in 1999 and the price of field corn went down. The decrease in prices was due to a combination of market forces largely unrelated to the introduction of *Bt* corn.

We conducted a partial budgeting analysis for grower benefits of field corn using three most recent year averages and obtained estimates of benefits from $38 million (about $2 per acre to $219 million (about $12 per acre) per year (table 3). Thirty-eight million dollars per year across 19.5 million acres of *Bt* corn implies benefits of less than $2 per acre which may be too close to the margin to make economic sense for many farmers. It is likely that benefits would be about $38 million or less in years of low insect pressure and benefits would be in the area of $219 million in years of high insect pressure. It may be clearer to state that benefits of *Bt* corn are likely to be less than a maximum of $219 million per year. They would be around $38 million or less in years of low infestations. There is considerable uncertainty regarding the magnitude of yield changes and the amount of the technology fee. The technology fee is charged by the seed dealer and can be subject to discounts due to market factors. It is likely that farmers who find planting of *Bt* corn to be a profitable move will lose money planting *Bt* corn in years of low insect pressure but that the expected gain (the returns from averaging out impacts over the years of high to low pest pressure) warrant planting *Bt* corn or that *Bt* corn is viewed as insurance against the high infestation years.

This partial budget estimate does not include the cost of the insect refuge. Acres planted to refuge would not obtain the gains of $12 per acre. That is, the grower would plan for the gain on up to 80 percent of field corn acreage.

The introduction of Cry1F *Bt* corn may result in additional acres being planted to *Bt* corn and/or could result in a shift in acres from another *Bt* corn products to Cry1F. It is reasonable to expect some corn growers have not planted *Bt* corn because the economic gain from control of European corn borers or Southwestern corn borers did not warrant *the cost, but* Cry1F *Bt* corn controls additional pests and its use may be warranted. We are not projecting the numbers of corn acres that may be impacted.

The partial budgeting estimates assume there are no price effects which would affect the distribution of benefits. Typically, if growers increase production, value per unit goes down implying some of the benefit is being passed to processors or the consumer resulting in less benefit to the growers. The other implication is non-adopters of the technology also will receive less money per acre (or per bushel) for their crop. These effects apply to any new technology which results in increased efficiency.

Table E. 3. Grower Benefits of *Bt* Field Corn (Partial Budgeting Approach)

Item	Unit of measure	Low Insect Pest Pressure**	High Insect Pest Pressure
Acres planted 1/	1,000	79,032	79,032
Yield 1/	bushels/acre	135.1	135.1
Acres *Bt* corn 1/	1,000	17,933	17,933
Yield increase 2/	bushels/acre	5.4	10.81
Value of yield change 3/	dollars/acre	10.11	20.21

Technology fee 4/	dollars/acre	8.00	8.00
Per acre benefit 5/	dollars	2.11	12.21
Total grower benefit 6/	1,000 dollars	37,758	218,979

1/ Three Year Average from Table E. 2.
2/ based on 4 to 8 percent yield increase from Marra et al. (1998) and from Carpenter and Gianessi (1999).
3/ change in yield times average grower price received of $1.87/bushel (Table E. 2.).
4/ The 1999 technology fee as estimated by Carpenter & Gianessi (1999)
5/ value of yield increase less technology fee.
6/ per acre benefit times acres *Bt* corn.
**This is intended to be representative of the lower bound benefits. Various conditions could result in actual benefits below this lower bound estimate for some years.

e. Mycotoxin Reduction

Mycotoxins are chemicals produced by fungi, that are toxic or carcinogenic to animals and humans. The most commonly occurring mycotoxins on corn are produced by the fungal genus *Fusarium*, and are known as fumonisins (Munkvold, 2000). There are several different kinds of fumonisins: FB_1, FB_2, FB_3, FB_4, FA_1, and FA_2 (Marasas, 1996; Ross et al., 1992). Another class of corn mycotoxins are those produced by the genus *Aspergillus*, including the notorious aflatoxins. The economic impact of aflatoxins is greater than that of other mycotoxins because they can be passed into milk if dairy cows eat contaminated grain (Munkvold et al., 1999).

Damage by insect pests such as the European corn borer can be an important factor for mycotoxin development in corn. Insect pests promote the growth of mycotoxin producing fungi in two ways: 1) They carry fungal spores from the plant surface to the surfaces of damaged kernels, and 2) They create entry wounds on the kernels for the fungi. Even when the insect pests do not directly carry fungal spores to the corn wounds, ambient spores deposited later on tissue wounded by pest feeding are more likely to infect the plant (Munkvold, 1999). Field studies have shown that damage due to southwestern corn borer (SWCB) can increase aflatoxin levels (Windham, et.al. 1999).

When mycotoxin contamination occurs in corn, the potential damages can be both economic costs to growers and health risks to humans and livestock. Corn grain that contains mycotoxins above a certain level is more likely to be rejected in the market, forcing growers to accept the lower price for non-food uses. In particular, the FDA's new proposed guidelines about recommended levels of fumonisins in grain may have a significant impact on amount of corn sold at the better food/feed prices. While these FDA guidelines for fumonisin levels are not yet set as action levels, they have been proposed to industry as safety thresholds (Randall A. Lovell, Center for Veterinary Medicine/ FDA, personal communication). The guidelines in human food and animal feed are shown in Tables E1 and E2.

Table E1. FDA guidelines for total fumonisins in human foods (FDA, 2001a).

<u>Product</u>	**Total Fumonisins (FB_1+FB_2+FB_3) parts per million (ppm)**
Degermed dry milled corn products (e.g., flaking grits, corn grits, corn meal, corn flour with fat content of < 2.25 %, dry weight basis)	2 ppm
Whole or partially degermed dry milled corn products (e.g. flaking grits, corn grits, corn meal, corn flour with	4 ppm
Dry milled corn bran	4 ppm
Cleaned corn intended for masa production	4 ppm
Cleaned corn intended for popcorn	3 ppm

Table E2. FDA guidelines for total fumonisins in animal feed (FDA, 2001b).

Animal or Class	**Recommended Maximum Level of Total Fumonisins in Corn and Corn By-Products (ppm[1])**	**Feed Factor[2]**	**Recommended Maximum Level of Total Fumonisins in the Total Ration (ppm[1])**
Horse[3]	5	0.2	1
Rabbit	5	0.2	1
Catfish	20	0.5	10
Swine	20	0.5	10
Ruminants[4]	60	0.5	30
Mink[5]	60	0.5	30
Poultry[6]	100	0.5	50

Ruminant, Poultry & Mink Breeding Stock[7]	30	0.5	15
All Others[8]	10	0.5	5

[1] total fumonisins = $FB_1 + FB_2 + FB_3$.
[2] fraction of corn or corn by-product mixed into the total ration.
[3] includes asses, zebras and onagers.
[4] cattle, sheep, goats and other ruminants that are ≥ 3 months old and fed for slaughter.
[5] fed for pelt production.
[6] turkeys, chickens, ducklings and other poultry fed for slaughter.
[7] includes laying hens, roosters, lactating dairy cows and bulls.
[8] includes dogs and cats.

Fumonisins are toxic to livestock, especially horses, swine, and cattle; and are carcinogenic in laboratory animals. The 1989 US corn crop had particularly high levels of fumonisins, resulting in dramatic increases in the horse disease equine leukoencephalomalacia (ELEM) and the swine disease porcine pulmonary edema (PPE) (Marasas, 1996; Ross et al., 1992). At the time of the 1989 mycotoxicosis outbreaks, FB1 concentrations in suspect swine feeds were 20-360 ppm, and in equine feeds were 8-117 ppm. Non-problem feeds contained concentrations below 8 ppm (Ross et al., 1992). Epidemiological studies have linked consumption of fumonisin-contaminated grain with elevated esophageal cancer incidence in humans (Marasas, 1996). A definitive link between fumonisin levels and human cancer is not possible from these studies due to the presence of possibly confounding effects in the study. Other documented toxicological effects of fumonisins in laboratory studies include toxicity and carcinogenicity in rats, cytotoxicity to mammalian cell cultures, and phytotoxicity to weeds and other plants including tomatoes (inhibiting growth and chlorophyll synthesis) (Marasas, 1996).

One of the benefits of Bt corn (a genetically modified, pest-protected corn) is that it has demonstrated drastically reduced occurrences of contamination by the mycotoxin fumonisin. This is because Bt corn is far less prone to insect injury, which in turn prevents the growth of fumonisin producing fungi. Certain events of Bt corn, such as MON810 and BT11, can reduce fumonisin levels by as much as 90% (Munkvold, 2000). This implies both private and social benefits: economic returns on corn sales would increase, and there would be potential reductions in mortality and morbidity among livestock and, presumably, humans.

Munkvold (2000) estimated that, if the current FDA guidelines for fumonisins in food were to become action levels, about 160 million bushels of corn in just the states of Iowa, Illinois, Missouri, and Nebraska would be at risk of rejection – an annual loss of value in the tens of millions of dollars in just these states. Depending on the amount of Bt corn planted in these states in lieu of conventional corn, the *savings* that Bt corn would afford might also range in the tens of millions. Vardon (2000) made similar predictions on potential economic losses due to fumonisins in corn, estimating an annual loss of $11 million. Hence, the economic benefits from Bt corn by this estimation is in the several millions. One of the reasons this value is lower than Munkvold's estimates (in the tens of millions of benefits) is that Vardon's model assumes that the corn that is rejected for food is still acceptable for animal feed. This in fact may no longer be the case, as FDA's most recent proposed guidelines in animal feed are at about the same level as for human food. Neither study calculates the costs of the fumonisin mycotoxin to human health, acknowledging the difficulty of extrapolating from available epidemiological studies directly to human health benefits.

Aflatoxins are known carcinogens to laboratory animals and presumably man; hence, the presence of aflatoxins in foods is restricted to the minimum levels practically attainable by modern processing techniques. Historically, aflatoxin levels in corn have been highest in the Southeastern states. Corn from anywhere in the US may be affected, however, depending on the growth, harvesting and storage conditions involved, as was the case with aflatoxin contamination in the Midwest in 1988 and Texas in 1987 (FDA, 1999).

Currently, the action level for aflatoxins in corn grain for human food is 20 ppb (FDA, 1994; Munkvold, 1999). When dairy animals consume feed containing high levels of aflatoxin, one of the metabolized aflatoxins (B_1) may be secreted into the animals' milk as aflatoxin M_1. Dairy cattle consuming corn feed that contains less than the FDA action level of 20 ppb total aflatoxins, however, should produce milk under the 0.5 ppb action level for aflatoxin M_1 in milk (FDA, 1999). In 1969, the FDA had established the action level of 20 ppb aflatoxins in all foods, including animal feed; however, subsequent tests showed that aflatoxin levels above 20 ppb could be fed to certain food-producing animals without endangering either these animals or consumers of food derived from the animals (FDA, 1994). The action levels for aflatoxins in corn are summarized in Table E3:

Table E3. FDA's action levels for corn aflatoxins in human and animal foods (FDA, 1994).

Product or animal	***Aflatoxin action level (ppb)***
Human food	20
Milk	0.5
Beef cattle	300
Swine over 100 lbs	200
Breeding beef cattle, swine, or mature poultry	100
Immature animals	20
Dairy animals	20

FDA compliance monitoring program from 1990 to 1996 indicate that 6.6 percent of corn samples exceeded the aflatoxin action level for food (Vardon, 2000). The potential value of crops lost because of aflatoxin contamination has been estimated to be $47 million per year in food crops (corn and peanuts) and $225 million per year in feed corn. The cost of livestock morbidity was estimated at $4 million per year (Vardon, 2000).

Studies comparing Bt with non Bt hybrids have usually show no significant difference in aflatoxin levels. The variability in aflatoxin levels due to environmental factors overwhelms the beneficial effects related to insect control seen in the current Bt products (Odvody 2001, personal communication). Even though insect damage ratings are lower for Bt hybrids, apparently the amount of insect feeding is sufficient for *A. flavus* establishment and subsequent aflatoxin contamination (Windham, et.al 1999). Studies across 10 states in 2000 found little or no aflatoxin to begin with, and in cases of substantial aflatoxin contamination, no significant differences were seen between Bt and non Bt hybrids (Headrick, 2001). Two studies in Alabama in 1999 also showed no difference in aflatoxin levels while yields were significantly higher for the Bt hybrids (Delamar, et. al, 1999).

A study in 1999 in Corpus Christi, Texas actually showed that under conditions of extreme drought and artificial inoculation with *A. flavus*, Bt corn hybrids had higher aflatoxin levels compared with non-Bt isolines (Odvody 2000). The study was expanded in 2000 to include more locations with mixed results in terms of aflatoxin contamination levels between Bt and non-Bt isolines. However, Bt corn hybrids had less aflatoxin contamination than the non-Bt hybrids, on average in 2000 when the comparison is done excluding one of the 9 Bt/non-Bt hybrids (Pioneer 3394). The author concludes that differences in individual hybrid susceptibility to infection by *A. flavus* was the primary factor influencing aflatoxin accumulation (Odvody 2001, personal communication). The reasons for the negative performance of the one particular commercial line are not known. Factors that were forwarded as hypothesis by the researcher are the particular adaptability of a hybrid in a region, differences in the test material (i.e., not true isolines), or unintended effects from the insertion of the Bt gene to the plant's natural defense system against infection. Better pest control is viewed as only one of many defenses in the attempt to develop hybrids with improved performance against aflatoxin contamination (Odvody 2001, personal communication).

e. Future Benefits

This analysis has used the benefits which have occurred from the adoption of *Bt* corn as a basis to project future benefits. It is expected that benefits will continue at about the magnitude of those for the period of the analysis. Individual growers will have more experience with *Bt* corn and should have the experience to determine whether the reduced damage warrants the additional cost for the technology. The European corn borer and the Southwestern corn borer cause significant damage in certain regions of this country most years. Those growers in these areas with regular infestations, will continue to utilize this technology and others with significant damage will adopt the technology. Those whose infestations is not serious, will not continue to utilize the technology. It will be interesting to see whether forecasting of insect problems can become sufficiently sophisticated to enable growers throughout major corn growing areas to know enough about the probability of an economic infestation to plant *Bt* corn only in those years when the problem will warrant it.

4. *Bt* Sweet Corn Plant-Incorporated Protectant

In 1998, EPA approved the registration of Syngenta's (formerly Novartis) Cry1Ab (*Bt*11) sweet corn. Major pests controlled are European corn borer (ECB), corn earworm (CEW), and fall armyworm (FAW). Approximately 742,000 acres of sweet corn is grown in the United States, including processed and fresh corn. EPA recently registered Cry1F *Bt* sweet corn which has control of the Black cutworm as well as the ECB, CEW and FAW. This material has not been available for a sweet corn growing season. Therefore, while the addition of Cry1F has the potential to increase acres planted to *Bt* sweet corn, we have not factored this new registration into the analysis.

Table E. 4 . Top States Growing Sweet Corn (Acres Planted in 1999)

State	Processed	Fresh	Total Sweet Corn
Minnesota	127,400	0	127,400
Wisconsin	107,100	8,900	116,000
Washington	99,400	2,100	101,500
New York	33,100	35,900	69,000
Oregon	44,200	6,900	51,100
Florida	0	38,900	38,900
California	0	31,000	31,000
Illinois	16,600	7,600	24, 200

State	Processed	Fresh	Total Sweet Corn
Pennsylvania	2,800	20,800	23,600
Georgia	0	22,000	22,000
Ohio	0	17,200	17,200
Idaho	15,900	0	15,800
Michigan	0	11,500	11,500
New Jersey	0	10,500	10,500
Selected States	446,400	213,300	659,700

Source: NASS, USDA, 2000

a. Potential to Replace Chemical Insecticides

Commercial field data studies for *Bt* sweet corn submitted by Syngenta suggest the potential to achieve equivalent yields to traditional varieties while reducing the quantity of insecticides used to control these pests. According to NASS data, about 3.3 million acre treatments of insecticide are applied annually to sweet corn. Based on the pest complex being targeted, the potential market for *Bt* sweet corn is 2.0 million acres, or 60% of total acre treatments (Doane, 1998). The major chemical insecticide alternatives are cyhalothrin-lambda, permethrin, and methomyl with esfenvalerate, carbaryl, chlorpyrifos, cyfluthrin, and methyl parathion. *Bt* microbial sprays are used to a lesser extent. (Doane, 1998).

b. Benefits for Sweet Corn

The majority of sweet corn acres are planted to processed corn while the value per acre of fresh corn is over 3 times the market value of processed corn.

Table E. 5. Value of Processed and Fresh Sweet Corn

Year	1997	1998	1999
Processed			
Acres Planted	478,900	486,400	473,400
Value ($000's)	250,329	238,748	234,448
Value/acre	522.72	490.85	495.24
Fresh			
Acres Planted	254,900	255,700	268,300
Value ($000's)	418,617	452,410	458,632
Value/acre	1,642.28	1,769.30	1,709.40
Total			
Acres Planted	733,800	742,100	741,700
Value ($000's)	668,946	691,158	693,080
Value/acre	911.62	931.35	934.45

Source: NASS, USDA, 2000

On average, sweet corn is treated for all insect pests 5.5 times per year: 4.3 times for processed corn and 8.6 times for sweet, although the variability is quite significant among states.

Table E. 6. Fresh Sweet Corn Insecticide Treatments, 1998 (thousands of acres)

State	Acres Planted	Acre Treatments	No. of Applications/Yr
California	31.0	389.4	12.56
Florida	38.9	657.6	16.9
Georgia	22.0	115.8	5.26
Illinois	7.6	30.3	3.99
Michigan	11.5	50.4	4.39

State	Acres Planted	Acre Treatments	No. of Applications/Yr
New Jersey	10.5	82.2	7.83
New York	35.9	136.2	3.79
Oregon	6.9	5.8	0.84
Washington	2.1	11.3	5.4
Wisconsin	8.9	36.7	4.12
Total for Top States	175.3	1,479.0	8.65

Source: NASS, USDA, 2000

A simulation model based on a demand curve for *Bt* sweet corn shows an average net benefit/acre of $3.55 for processed corn and $5.75 for fresh corn. Upper limits benefits for *Bt* sweet corn are based on savings from reduced insecticide applications. An upper limit application savings of $45/acre is based on 9 applications per year, 60% (5.4) of which target *Bt* pests, and each application costs an average of $8.25 per acre (Doane, 1998). The source for market share estimates for *Bt* sweet corn is USDA's Pest Management Practices 1999 summary. The USDA estimated 4% of vegetables in 1999 were planted with genetically modified seed to resist insects and sweet corn is the only crop with a registered plant-incorporated protectant. However, Syngenta Seeds considers their market share information for *Bt* sweet corn information to be confidential business information. Information available from USDA indicates the quantity of *Bt* plant-incorporated protectant on all vegetables for 2000 was too small to quantify (*Bt* plant-incorporated protectants for vegetables are only registered for use on potatoes and sweet corn). If we assume less than 5% of sweet corn is *Bt* sweet corn, seed premium cost $30/acre (personal communication: Warnick, Debra, Novartis Seeds, Inc [year]), upper limit benefits $45/acre, and upper limit *Bt* specific costs are $58/acre (which is 6.2% of the average value per acre grown in 1999). Net benefits are $5.38/acre.

Table E. 7 Estimated Benefits for *Bt* Sweet Corn

Item	Unit of Measure	Value
Acres planted	acres	739,200
Average benefits to *Bt* adopters	dollars per acre	40

Average other costs to *Bt* adopters	dollars per acre	5
Technology fee	dollars per acre	30
Net benefit	dollars per acre	5
Insecticide treatments saved	per *Bt* acre	4.8

Source: Acres planted-average from Table E.5

Average benefit to *Bt* adopters was estimated by the simulation model using the subset of observations for which benefits exceeded all costs.

Other costs (insect resistant management, discounts for marketability, and underlying hybrid yield) equals the average cost to the adopters using the subset of observations for which benefits exceeded all costs. Other costs have been estimated indirectly by the model.

Technology fee is the seed premium.

Net benefit equals average benefit less other costs less technology fee.

Insecticide treatments saved equals average benefit divided by average treatment cost ($8.25 per treatment) based on the assumption that the principal benefits are reduction in treatment costs.

The average *Bt* sweet corn user must cover all costs (the seed cost premium & other costs), and if benefits are mainly to reduce cost, then use reduction can be deduced from the average benefits plus seed cost premium divided by the chemical cost per acre. At a cost per treatment of $8.25 and average benefit of $40.00/acre, the use reduction of 4.8 treatments per year. Applied to the 29,600 acres assumed treated with *Bt* plant pesticides, total pesticide use reduction is estimated to be 142,000 acre treatments for 1999.

c. Environmental Benefits of *Bt* Sweet Corn

A number of comments addressed the potential environmental benefits of *Bt* sweet corn.

Because of the low adoption rates, potential benefits have not been realized. Biorationals with novel modes of action have not significantly replaced the more acutely toxic organophosphate and pyrethroid insecticides. *Bt* sweet corn allows a transition to more selective toxins and increase the beneficial arthropod community (Fleisher, 2000). The benefits of reducing toxic insecticide use are as follows:

1. Sweet corn in Florida is still mostly hand picked and packed in the field. Detasseling operations also bring workers into direct contact with sweet corn (Nuessley, 2000).

2. Maryland growers of sweet corn and potatoes are concerned about worker exposure risks and believe that the *Bt* technology offers an alternative to toxic insecticides (Dively, 2000).

3. Studies in Maryland conducted in 1999 clearly showed that BT11 corn had significantly less fumonism contamination of up to 96% compared to its non-transgenic isoline (Dively, 2000).

4. Adoption of *Bt* corn (field and sweet corn) may help an areawide suppression of the corn earworm since corn serves as the primary nursery for recruitment of CEW populations, which later in the season infest soybeans, lima bean and tomatoes. Further insecticide use reductions could therefore occur in these other crops as well as corn (Dively, 2000).

d. Future Benefits

Information available suggests adoption of *Bt* sweet corn has not grown as expected which implies fear of consumer rejection or that the technology is not working as expected. We expect the seed companies marketing this technology will resolve any technology problems and consumers will accept the product in time.

5. *Bt* Cotton Plant-Incorporated Protectant

a. Usage Estimates

Cotton is grown throughout the southern regions of the United States. Highest yielding cotton has been the irrigated cotton grown largely in desert areas of California and Arizona.

The two types of cotton grown in the U.S. are upland and pima cotton, but upland is more common (about 98 percent of cotton acres are upland) and is the only cotton currently producing the *Bt* protein. *(Bt* cotton is the acronym given to cotton engineered to express *Bt* Cry1Ac protein).

This pesticide was registered in the United States in 1995 with commercial plantings commencing in 1996. The registrant has provided data to the EPA showing that about 1.8 million acres of *Bt* cotton were planted in 1996 which increased to about 4.4 million in 2000. However, USDA's estimates of acres planted with *Bt* Cotton are slightly less than Monsanto's estimates. USDA's estimates were based on a sample of farmers' survey responses while Monsanto used sales data by state to estimate the acres planted.

Bt cotton adoption rates have been highest in Arizona and lowest in Kansas, Missouri, Texas, and California. A pink bollworm eradication program conducted in part of California was quite successful and reduced the usefulness of *Bt* cotton to growers in that State.

Table E. 8. Cotton Production and *Bt* Cotton Adoption Rates (1998-2000 average)

State	Cotton Acreage	*Bt* Cotton Acreage	% of Cotton Acreage in *Bt* Cotton
Alabama	550,000	340,000	62
Arizona	267,000	205,000	77
Arkansas	950,000	193,000	20
California	678,000	58,000	9
Florida	109,000	49,000	47

Georgia	1,447,000	594,000	41
Kansas	30,000	352	0.9
Louisiana	620,000	359,000	57
Mississippi	1,150,000	684,000	59
Missouri	383,000	9,400	2
New Mexico	80,100	15,000	20
North Carolina	840,000	259,000	29
Oklahoma	227,000	57,000	23
South Carolina	307,000	126,000	40
Tennessee	530,000	276,000	49
Texas	6,067,000	435,000	7
Virginia	104,000	11,000	10
U.S.	14,337,770	3,673,018	26

Source: Crop Production, 2000 Annual Summary, USDA/NASS

Crop Value, 2000 Annual Summary, USDA/NASS

Bt cotton acres as reported by the Registrant in terms of quantity sold and converted to acres by EPA staff.

State averages can be somewhat misleading since there is wide variability in yields depending on growing conditions. For example, in 2000, Texas accounted for more that 40 percent of the U.S. acres planted to cotton yet only about 9 percent of acres were planted to *Bt* cotton. Since, a large portion of cotton acres in Texas did not receive insecticide applications, it is reasonable to assume that the majority of growers in Texas would not adopt *Bt* cotton since they would not benefit from it. According to the usage estimates available about 90 percent of Texas cotton acres were not *Bt* cotton.

b. Insect Pests

The *Bt* protein targets Lepodepteran insects (the juvenile stage are called worms) including pink bollworm, tobacco budworm and to a lesser extent the bollworm. It also provides some suppression of the fall armyworm, the beet armyworm and southern armyworms.

The boll weevil, bollworm, budworm and pink bollworm are major pests of cotton. In some areas, the pink bollworm or the bollworm/budworm complex are the major pests, but for most of the US cotton belt, boll weevils (not controlled by *Bt*) have been the major insect pest. The boll weevil eradication program is well on its way to eliminating the boll weevil as an economic pest of cotton in most of the cotton growing regions of the U.S. Prior to the boll weevil eradication program, the chemical insecticides used against the boll weevil resulted in control of most other insects on cotton including bollworm and budworm. The eradication program uses malathion against the boll weevil which controls many other secondary pests, also kills beneficial (predatory) insects, and only suppresses the worm complexes. Therefore, there has been an explosion of the worm complex which farmers had been controlling with conventional pesticides. According to USDA/ARS (USDA/ARS 2001) once *Bt* cotton was available, farmers in the boll weevil eradication program who planted *Bt* cotton used substantially fewer applications of conventional foliar pesticides, and secondary pests could be treated with more selective and less harmful pesticides than the broad spectrum pesticides typically used in the past.

c. Grower Benefits

Cotton is produced in all of the states across the southern tier of the U.S. (Table E. 9.). Since *Bt* cotton is an upland cotton, this analysis considers only impacts on upland cotton production. About 14.4 million acres are planted annually with a value of $4.6 billion.

Table E. 9. 1998-2000 National Upland Cotton Data

Item	Unit of measure	1998	1999	2000	Average

Acres planted	1,000 acres	13,064.3	14,684	15,365	14,371
Acres *Bt* cotton	1,000 acres	2,486	3,585	4,410	3,494
Production					
Lint	1,000 bales	13,475.9	16,293.7	16,822.0	15,530.5
Cottonseed	1,000 tons	5,365.4	6,353.5	6,438.6	6,052.5
Yield					
Lint	pounds	619	595	625	613
Cottonseed	Tons	0.41	0.43	0.42	0.42
Crop Value					
Lint	1,000 dollars	3,923,827	3,533,825	4,597,962	4,018,538
Cottonseed	1,000 dollars	687,179	559,157	677,131	641,156
Price/pound of lint	dollars	0.60	0.45	0.56	0.54
Price/ton of cottonseed	dollars	129.00	89.00	106.00	108.00

Source: Crop Production, 2000 Annual Summary, USDA/NASS

Crop Value, 2000 Annual Summary, USDA/NASS

A number of studies have examined the direct farmer benefits of growing *Bt* cotton. However, most of these studies have been for limited areas within the cotton growing areas, and have been confounded by the boll weevil eradication program taking place during the same time period. Marra et al (1998) estimated the net benefit to growers using *Bt* cotton in 1996 to be about $51 per acre **. The authors estimated changes in yield, pesticide use, and profits from use of *Bt* cotton in North Carolina/Virginia and Alabama/Georgia. They found an increase in profit averaging $50.82 for the entire sample with profits increasing by $30.01 in NA/VA although yield changes were non-significant and profits increasing to $60.27 in AL/GA with significant changes in yield. They also found an average reduction in conventional pesticides of 1.97 sprays across the sample from adoption of *Bt* cotton. Unfortunately, the study did not report average numbers of sprays for all of the states examined, but for GA the average number of sprays

** This sentence has been changed from the September 29 version.

decreased from 7.72 in 1996 to 1.05 in 2000. Part of this reduction probably came from the boll weevil eradication program being completed in GA. A big decrease came in 1996 and 1997 the average number of sprays decreasing from 7.72 to 2.95 and the average number of insecticide applications is continuing to decrease. This is consistent with the discussion in the Insect Pest section above. Alabama had on average less than one application in 2000, vs. 1.47 in 1997.

Frisvold et al. (2000) conducted a study of 3 years of *Bt* cotton (1996-1998) and estimated net U.S. benefits of *Bt* cotton to be about $66 million for 1998. Cotton producers gained about $88 million, and cotton purchasers gained about $55 million while the taxpayer paid an additional $78 million in payments to cotton farmers.

Cooke et. al. (2000) conducted a study of the impacts of *Bt* cotton on 13 to 15 farms in the Mississippi Delta and found yields increased by about 1 pound per acre with *Bt* cotton and insect control costs favored *Bt* by about $4 per acre. However, the years studied were years of very light infestations of the bollworm and budworm. USDA estimated a small yield advantage for *Bt* cotton of about 87 pounds in Mississippi (and this was prior to the boll weevil eradication program beginning in Mississippi). Grower benefits are likely to be higher in years with higher infestations of bollworms and budworms.

As discussed above, *Bt* cotton was planted on about 4.4 million acres of cotton in 2000 and EPA assumes that farmers expect to receive benefits at least equal to the monetary value of the payment to seed companies for the technology fee, since the *Bt* cotton adoption rate continues to increase .

A partial budgeting analysis of the probable benefits for the entire cotton growing region for the 1998-2000 period obtained per acre benefits of $17 to $36 and total farmer benefits between $60 and $126 million (on the *Bt* acres). Lower bound estimates could be high for years of low pest pressure and upper bound estimates cover the likely gains in worst case years assuming a yield gain of about 12%. It is likely that the upper bound estimates would not cover all of the acres planted to *Bt* cotton during the same year which implies the $126 million estimate is too high. However, there are not sufficient years of experience with both *Bt* cotton and the boll weevil eradication to reach firm conclusions.

It has been alleged that some portion of cotton growers had no choice but to purchase *Bt* cotton if they wished to plant Roundup Ready cotton. To the extent that growers had no choice, and would have planted just Roundup Ready cotton, benefits for *Bt* cotton would have been overstated. These growers may have had some benefit from *Bt* cotton but if we are basing our estimates on the assumption that growers are planting *Bt* cotton where information indicates planting is economically warranted. This problem is probably less than could be implied since we used a three year average of *Bt* cotton acres and the practice of not providing some growers with a choice supposedly began in 2000.

Table E. 10. Grower Benefits of *Bt* Cotton (Partial Budgeting Approach)

Item	Unit of measure	Low **	High
Acres planted 1/	1,000 acres	14,371	14,371
Lint yield 1/	pounds/acre	613	613
Cottonseed yield 1/	tons/acre	0.42	0.42
Acres *Bt* Cotton 1/	1,000 acres	3,493.67	3,493.67
Yield increase 2/			

Item	Unit of measure	Low **	High
Lint	pounds/acre	42.91	73.56
Cottonseed	tons/acre	0.03	0.05
Value of yield increase 3/			
Lint	dollars/acre	23.17	39.72
Cottonseed	dollars/acre	3.18	5.44
Technology fee 4/	dollars/acre	25.00	25.00
Chemical savings 5/	dollars/acre	16.00	16.00
Per acre benefit 6/	dollars/acre	17.35	36.17
Total grower benefits 7/	1,000 dollars	60,503.3	126,350.67

1/ Table E. 9

2/ Cottonseed/ lint yield times 7 or 12 percent estimated yield increase.

3/ Yield increase times value of yield (Table E. 9.).

4/ Technology fee varies and was assumed to average $25.00 per acre.

5/ An average savings of two insecticide applications at $8.00 per application.

6/ value of yield increase plus value of chemical savings less the technology fee.

7/ Per acre benefit times acres *Bt* cotton.

**This is intended to be representative of the lower bound benefits. Various conditions could result in actual benefits below this lower bound estimate for some years.

Since the use of *Bt* cotton has been growing and farmers have been paying significant fees to the registrant, this implies that the private benefits to the farmers exceed the technology fee paid to the registrant. The exact magnitude of this benefit is not clear due to many uncertainties such as, confounding effects due to varying status of the boll weevil eradication program, the number of pesticide sprays not needed, the actual pest infestation levels, and fluctuations in cotton prices

There is no indication that any of these studies included the costs of resistance management programs. The resistance management program in 2001 gave options of a 5 percent unsprayed refuge, a 20 percent sprayed refuge, or an embedded 5 to 10 percent refuge. If there was a significant bollworm/budworm problem, it is likely that losses in the unsprayed refuges would be quite high, perhaps as high as 40 percent (National Cotton Council, 2000). Growers choosing the 5 percent unsprayed refuge option could be faced with large production losses in the refuge implying that the gain would not be as high as estimated above. Growers who chose the 20 percent sprayed option could assume 20 percent of their crop does not get the *Bt* program benefit, but could be sprayed with non-*Bt* chemical pesticides.

It seems reasonable to assume the sprayed refuge would have a production/cost profile similar to conventional cotton. If insect sprays are effective against those pests targeted by *Bt* cotton and timed to target those pests, then yields should be close to those of *Bt* cotton without any refuge.

The recent option of an embedded 5 to 10 percent refuge allows the grower to use chemical insecticides if necessary and still have the desired ratio of susceptible to resistant insects described in the Insect Resistance Management chapter. If the embedded refuge for budworm or bollworms is sprayed, the whole area, including the *Bt* cotton, would have to be treated with the chemical insecticide in order to maintain the efficacy of the refuge. This option should reduce the yield loss compared to an unsprayed refuge, but it imposes additional costs for the use of chemical pesticides across all of the cotton acres. While theoretically this may lengthen the number of years to the development of resistance, it is not clear how growers will respond to the wide variability in pest pressure and the need to consider spraying an area larger than the refuge. The embedded refuge requires more effort to design, plant and manage in order to determine needed pesticide sprays. The extra expense of treating all of the acres may reduce the likelihood that growers would add additional sprays if there were significant pest damage to the embedded refuge.

The Partial budgeting estimates assume there are no price effects which would affect the distribution of benefits. Typically, if growers increase production, the increase in supply causes value per unit goes down implying that some of the benefit is being passed on to processors or the consumer resulting in less benefit to the growers. The other implication is non-adopters of the technology also will receive less money per acre for their crop. These effects apply to any new technology which results in increased efficiency.

d. Environmental Benefits of *Bt* cotton

In addition to the potential direct benefits to the grower from: 1) reduced pesticide use, 2) improved crop management effectiveness, 3) reduced production costs, 4) improved yield–5) reduction in farming risk, and 6) improved opportunity to grow cotton in areas of severe pest infestation; significant indirect (or environmental) benefits may also be gained from *Bt* cotton including: 1) improved populations of beneficial insects and wildlife in cotton fields, 2) reduced pesticides runoff, 3) reduced air pollution and waste from the use of chemical insecticides, 4) improved farm worker and neighbor safety, and 5) reduction in fossil fuel use.

It might also be argued that increased yields would require less land to produce the same quantities of cotton potentially resulting in less land devoted to agriculture. The extra land could increase wildlife habitat for example. While this argument is intuitively appealing, it is too complex a benefit to measure and current data indicate that cotton acreage is actually increasing.

As stated in the SAP review, farm level data are needed to properly quantify the environmental benefits of *Bt* cotton. Ideally, one could compare identical situations except that one grower used *Bt* cotton and the other did not. However since those data are not available we must draw conclusions from trend data which is suggestive, but not definitive.

Trend analysis is also complicated by the boll weevil eradication program that started in the Carolina's in 1983 (MSU http://130.18.148.205/webpage/webpage_history.htm). The boll weevil and the bollworm/budworm complex are the major pests treated in cotton. The introduction of *Bt* cotton in 1996 appears to have accelerated the rate of pesticide use reduction.

Bt cotton yields larger environmental benefits when there is no need to control for the boll weevil, since more use can be made of beneficial predator insects. Historically, broad spectrum insecticides were used to simultaneously control boll weevil and budworm/bollworm. With *Bt* cotton and the absence of boll weevil infestation, further pesticide use reductions (and dollar savings) can occur because secondary pest problems can be controlled with beneficial insects.

The recently released Pest Management Practices Summary (USDA, NASS May 2001) show significant improvements in IPM practices since 1997, the year the first surveys were undertaken. The improvements form 1999 to 2000 are worth noting. As a percent of all acres for cotton:

1. Use of biological pesticides for pest suppression has gone from 15% to 47%
2. The use of beneficial organisms has increased from 5% to 32%
3. Growers say they alternate pesticides more often - from 44% to 67%

i. Chemical Alternatives to *Bt* Cotton

A large number of chemical pesticides are registered to control the worm complex that can attack cotton. Several reports have identified the most frequently used pesticides which are most likely to be replaced by *Bt* cotton (e.g., Gianessi and Carpenter, 2000 for a review). The table below is a collection of the suggested major alternatives and their pesticide classes.

Table E. 11. Major Chemical Insecticides Alternatives for *Bt* Cotton

Chemical Class	Pesticide Common Name
OP	Methyl Parathion
Pyrethroid	Lambda-cyhalothrin
Pyrethroid	Cyfluthrin
OP	Acepahate
Pyrethroid	Cypermethrin
Pyrethroid	Zeta-cypermethrin
OP	Profenofos
Pyrethroid	Esfenvalerate
Carbamate	Thiodicarb
Pyrethroid	Deltamethrin
Pyrethroid	Tralomethrin

Chlorinated Hydrocarbon	Endosulfan
Other	Spinosad
Carbamate	Methomyl
Other	Amitraz

The toxicity of these insecticides is high to both humans and non-target wildlife. Table E. 12 provides a sample of the label precautionary statements. Almost all are restricted use products which require the application or supervision of a certified applicator and require personal protective equipment to be worn during application due to concerns about acute toxicity to humans. Most have warnings stating that they are fatal if swallowed or absorbed through the skin. In addition to hazards to humans, many have significant environmental hazards.

Table E.12. Sample of Cotton Insecticide Label Precautionary Statements

Pesticide Common Name	Signal Word	Health Warnings	Environmental Hazard
Methyl Parathion	Warning	Fatal if swallowed	Hazardous to bees; Highly toxic to aquatic invertebrates and wildlife; Birds in treated areas may be killed; Shrimp may be killed at recommended label rates
Lambda cyhalothrin	Warning	May be fatal if swallowed, causes moderate eye irritation, repeated skin contact may cause allergic reactions	Extremely toxic to fish and aquatic invertebrates; Highly toxic to bees

Pesticide Common Name	Signal Word	Health Warnings	Environmental Hazard
Cyfluthrin	Danger	Corrosive; Causes irreversible eye damage; May be fatal if inhaled; Harmful if swallowed or absorbed through skin	Extremely toxic to fish and aquatic organisms; Toxic to wildlife; Extremely toxic to bees
Acephate	Caution	Harmful	Toxic to birds; Highly toxic to bees
Zeta-cypermethrin	Warning	Fatal if swallowed	Extremely toxic to fish and aquatic invertebrates; Highly toxic to bees
Larvin 3.2 Thiodicarb	Warning	Fatal if swallowed	Toxic to fish, birds, invertebrates and other wildlife
Methomyl Lannate SP	danger	Fatal if swallowed may be fatal if inhaled or absorbed through eyes harmful if absorbed through skin	Toxic to fish and other wildlife highly toxic to bees
Malathion	Caution	Harmful if swallowed	Toxic to fish, aquatic invertebrates birds: none bees: highly toxic
Aldicard Temik	Danger	Fatal if swallowed, may be fatal or harmful by contact with skin, eyes, or inhaled as dust	Toxic to fish, birds and wildlife groundwater advisory

Pesticide Common Name	Signal Word	Health Warnings	Environmental Hazard
Curacron 8 E Profenofos	Warning	May be fatal if absorbed through skin; Causes eye irritation; May be harmful if swallowed or inhaled	Hazard to endangered fish; Prohibited use in a Texas county and near fish hatchery in NM

Source: Crop Data Management Systems, Inc. http://www.cdms.net/manuf/manuf.asp

iii. Environmental Benefits through Use Reduction

Reducing the use of pesticides more toxic than *Bt* can reduce the risks to workers and bystanders, the risks to non-target insects and wildlife, and the risks from pesticide run-off. Although these benefits are difficult to quantify, reviewing the list of chemicals in the above table clearly indicates that such benefits could be obtained through reduced use of the products and substitution of safer pest control methods such as *Bt* cotton.

According to the National Center for Food and Agricultural Policy, cotton accounts for 30% of total agricultural insecticide acres treated in 1997 (NCFAP web site, 1997 data). Cotton insecticide use has been declining, particularly for the conventional insecticides used in place of *Bt* cotton. Although it is not uniform across the Cotton Belt, USDA's NASS survey data show reductions in chemical pesticide use for the budworm/bollworm complex as does data from the Mississippi State University.

Differences exist among regions depending on the extent of budworm, bollworm and boll weevil infestations. Since it is difficult to separate the influences of the boll weevil eradication and IPM programs from *Bt* cotton, the analysis shows the trend for all cotton insecticides. Products used in boll weevil eradication (mostly malathion) have not been included since it is unclear whether all malathion use was included in the early years of the NASS Agricultural chemical use surveys.

Table E.13 show that cotton has experienced a very large reduction in conventional insecticide usage. Comparing the period prior to the introduction of *Bt* cotton (1993 to 1995) to the latest year available (2000), show a two thirds decrease for the most toxic products to birds and fish, and a one third decrease for the most toxic products to humans.

Table E.13 Trends in Cotton Insecticide Use

Classified by signal word for human acute toxicity.

(Acre treatments per acre grown)

Year	Caution	Warning	Danger
1993	0.12	2.29	1.13
1994	0.23	2.91	1.43
1995	0.36	2.94	1.64
1996	0.25	1.51	0.95
1997	0.2	1.14	1.13
1998	0.32	1.19	0.97
1999	0.29	0.61	1.03
2000	0.30	0.49	0.86

Classified by Terrestrial Environmental Hazards

Year	No Warnings	Toxic Warning	Extremely Toxic
1993	0.67	1.32	1.55
1994	1.07	1.54	1.97
1995	1.30	2.01	1.62
1996	0.79	0.99	0.92
1997	0.69	0.98	0.82
1998	0.83	0.98	0.67
1999	0.43	0.85	0.66
2000	0.45	0.71	0.49

Classified by Aquatic Environmental Hazards

Year	Low to Toxic	Extremely Toxic
1993	1.11	2.43

1994	1.45	3.12
1995	1.85	3.09
1996	0.92	1.78
1997	0.99	1.49
1998	1.01	1.46
1999	1.01	0.92
2000	0.87	0.77

Source: NASS Agricultural Chemical Use Surveys

Impact of less toxic insecticide use on bird populations

The dramatic reduction in the avian toxicity of cotton pesticides does correlate with increases in average bird counts, based on data from the North American Bird Breeding Survey, Puxtent Wildlife Research Center, USGS. Comparing the 5 years prior to the introduction of *Bt* cotton (1991 to 1995) with the 5 years after (1996 to 2000) show that bird counts have increased, and are positively correlated with the *Bt* adoption rates, the reduction in insecticide use, and the relative presence of the specie in cotton fields. It should be noted that the correlations are suggestive of a cause and effect relationship, but do not prove it.

Tables E. 14 show the average count from the North American Bird Breeding Survey. The bird specie observed in cotton fields are taken from a report submitted to EPA titled "A Characterization of Avian Species On and Around Cotton Fields in the Cotton Belt of the Southern United States". 1/15/1998. Data were collected in 1995.

Table E.14 Percent change in Birds found in Cotton Fields

Species found in cotton fields in 1995	Average count (BBS) 1991-95	1996-2000	Percent change	% observed in cotton in 1995
Alabama				
barn swallow	16.65	23.47	41%	100.0%
carolina chickadee	7.41	9.75	32%	8.3%
chimney swift	14.36	15.97	11%	70.1%
common grackle	21.18	22.53	6%	38.9%
indigo bunting	22.8	33.38	46%	34.1%
northern cardinal	40.06	50.36	26%	18.5%
ruby throated hummingbird	0.39	0.68	74%	57.7%
american goldfinch	1.13	1.73	53%	39.1%
prothonotary warbler	0.91	0.92	6%	30.8%
mourning dove	30.77	37.98	23%	7.8%
blue grosbeak	5.21	8.39	61%	25.0%
Simple average for Alabama			**34%**	
Arizona				
abert's towhee	1.2	1.79	49%	50.1%
brown headed cowbird	4.83	4.97	3%	35.0%
cliff swallow	4.12	9.59	133%	99.2%
common yellowthroat	0.54	0.68	26%	36.8%
lark sparrow	5.06	2.22	-56%	35.0%
red winged blackbird	15.02	26.22	75%	82.2%

Species found in cotton fields in 1995	Average count (BBS) 1991-95	1996-2000	Percent change	% observed in cotton in 1995
verdin	10.99	9.7	-12%	56.8%
gambels quail	20.98	16.01	-24%	26.9%
mourning dove	32.76	27.62	-16%	17.9%
Simple average for Arizona			**20%**	
Mississippi				
barn swallow	10.24	14.25	39%	100.0%
carolina chickadee	4.77	4.86	2%	8.3%
chimney swift	6.05	6.56	8%	70.1%
common grackle	9.37	12.91	38%	38.9%
indigo bunting	13.03	20.75	59%	34.1%
northern cardinal	28.62	39.22	37%	18.5%
ruby throated hummingbird	0.63	0.63	0%	57.7%
prothonotary warbler	1.00	2.46	146%	30.8%
mourning dove	21.6	26.86	24%	7.8%
blue grosbeak	3.75	4.31	15%	25.0%
Simple average for Mississippi			**37%**	
Texas				
barn swallow	11.84	9.78	-17%	73.5%
indigo bunting	3.59	2.69	-25%	23.7%
northern cardinal	30.85	30.93	0%	20.7%
northern rough winged swallow	0.41	1.08	163%	100.0%
dickcissel	11.05	7.86	-29%	71.7%
lark sparrow	8.49	7.84	-8%	44.0%
mourning dove	42.79	44.67	4%	21.0%
common nighthawk	7.23	6.36	-12%	84.2%
brown headed cowbird	10.08	10.58	5%	19.0%
Simple average Texas			**10%**	

Sources: North American Bird Breeding Survey, USGS; Characterization of Avian Species On and Around Cotton Fields in the Cotton Belt of the Southern United States", American Cyanamid and Wildlife International 1/15/1998.

In terms of total bird count, the increase for all species for the four states is 16%. However, count increases are higher for species with a smaller initial count. The increase is 37% for population counts of 7 or less in 1991 to 1995 period, versus 15% for populations above 7. Since measures of bio diversity (such as the Brillouin) reflect the relative specie abundance and so should also likely improve.

Statistically significant correlations exist between the increase in bird counts (BBS counts) and the reduction in insecticide use, and to a lesser extent, the *Bt* adoption rate and the percent of the specie found in cotton fields (1995 report by American Cyanamid/Wildlife International), as summarized in the table below. Unfortunately, the 1995 study combined the Mississippi and Alabama data (presence of species found in cotton fields, number observed in cotton and total number observed).

Table E.15 Multiple regression significance tests

(Bird count by specie/state is the independent variable)

Dependent variable	T-statistic	Significance Level
Use reduction	2.8	99.5%
Bt adoption rate	1.7	95.2%
% species observed in cotton fields to total	1.4	91.1%
Arizona	4.4	99.8%
Texas	1.4	90.3%
Mississippi/Alabama	0.1	Not significant

Additional analyses have yet to be performed that may further define the relationship between use reduction and bird counts. These include adding species not found in cotton fields, and a more detailed geographic assessment. Route level data can be compared to county level *Bt* adoption rates.

Pesticide Runoff

A study by the USDA Agricultural Research Service (Becker, 2001) examined insecticide runoff from *Bt* cotton and conventional cotton. To measure pesticide runoff, the scientists planted cotton that was genetically engineered to contain a toxin from the bacterium *Bacillus thuringiensis*. Researchers planted the *Bt* cotton near Beasley Lake in Sunflower County--one of three watersheds within ARS' Mississippi Delta Management Systems Evaluation Area project. Because *Bt* cotton produces its own insect-inhibiting toxin, less pyrethroid insecticide is needed to control budworm and bollworm infestations.

From 1996 through 1999, runoff samples were analyzed for insecticides from both *Bt* cotton and non-*Bt* cotton fields. The researchers looked especially for pyrethroids and organophosphates because of their widespread use throughout the 7,000-square-mile, cotton-producing area. The fewer pyrethroid applications needed on *Bt* cotton sites reduced the amount of pesticides released into the environment. While runoff from non-*B*t cotton sites contained very slight amounts of pyrethroid insecticides, runoff from *Bt* cotton sites had almost none at all. The team found only insignificant amounts of organophosphate insecticides used to control boll weevils in runoff from either the *Bt* or non-*Bt* cotton sites. The scientists concluded that there are no detrimental environmental effects from either pyrethroid or organophosphate insecticides in runoff from any of the watershed sites sampled during this study.

While this is only one study, it is an indication that insecticide runoff may be reduced through the use of *Bt* cotton. Other studies are needed to confirm these results in other locations.

iv. Recent EPA Assessments of Alternatives

EPA recently conducted comprehensive reviews for some of the organophosphate and carbamate insecticides that *Bt* cotton replaces. The risk assessments for Methyl Parathion (as of 2/8/2001), Acephate (2/3/2000), and Profenofos (August 2000), and Methomyl and Thiodicarb Reregistration Eligibility Documents (12/1998) provide examples of some of the risks that can be reduced or eliminated through the use of safer pest control practices including *Bt* cotton.

1) Methyl Parathion

Methyl Parathion has the most significant reduction in use since 1995 when *Bt* cotton was first registered. On average, use of methyl parathion on cotton has gone from an average of 1.4 treatments per acre to 0.14 in year 2000. That's a 10-fold (90%) decrease.

a) Human Health Effects

Workers can be exposed to a pesticide through mixing, loading, or applying the pesticide, and re-entering a treated site. Worker risk is estimated by a Margin of Exposure (MOE) which determines how close the occupational exposure comes to the no observable adverse effects level (NOAEL) taken from animal studies. Generally, MOEs that are greater than 100 do not exceed the Agency's risk concern. For workers entering a treated site, Restricted Entry Intervals (REIs) are calculated to determine the minimum length of time required before workers or others are allowed to enter.

In the EPA's risk assessment for methyl parathion, the use of protective clothing and other risk reduction measures give acceptable MOEs for nearly all of the short- and intermediate-term occupational exposure scenarios. The post-application risks to reentry workers exceed the level of concern based on current (REIs) and application rates. Symptoms of exposure to methyl parathion include headaches, diarrhea, nausea, bloody nose, blurred vision, memory lapses, weak legs disorientation, vomiting.

b) Ecological Risks

Evidence exists in the open literature that methyl parathion may hinder successful reproduction and sexual development in non-target organisms, such as birds, mammals, and fish.

Methyl parathion is "very highly toxic" to birds. The level of certainty in this assessment is high. Studies indicate that a series of effects occur with short exposure to methyl parathion.

These include direct mortality, as well as acute sub-lethal effects such as reproduction effects, changes in maternal care and viability of young birds, anorexia, increased susceptibility to predation, and greater sensitivity to environmental stress. Most of the uncertainty in the terrestrial risk assessment is associated with terrestrial exposure.

Methyl parathion is "very highly toxic" to aquatic invertebrates and is likely to lead to adverse effects in these organisms. Estimated environmental concentrations suggest that levels of concern for acute toxicity to freshwater fish are exceeded only at the highest use rate, although there is high uncertainty in this analysis. Other data suggest the potential for indirect effects to freshwater fish from methyl parathion exposure. Methyl parathion use appears to pose significant acute risk to estuarine and marine fish, although there is much uncertainty associated with the exposure component of this analysis.

Extensive data over 20 years indicate that methyl parathion is "very highly toxic" to honey bees, and that bee kill incidents continue to occur. Currently, warning language is on labels for the microencapsulated Penncap-M formulation because the microencapsules are inadvertently collected by honey bees along with pollen. Studies suggest that the emulsifiable concentrate formulation of methyl parathion is also hazardous to bees.

2) Acephate

Acephate use has gone from 0.35 treatments per acre in 1995 to 0.18 treatments per acre in 2000. Acephate is noted to be effective at controlling a number of pests other than bollworm and budworm.

a) Human Health Effects

Acephate can cause cholinesterase inhibition in humans, which at high doses results in nausea, dizziness, confusion, and, at very high exposures (e.g. accidents, major spills), respiratory paralysis and death. All acephate products require personal protective clothing. Such as, long sleeved shirt and long pants, shoes plus socks and chemical resistant headgear. EPA's assessment indicated that Acephate risk from drinking water derived from surface water are high for infants and children. The methamidophos (a pesticide and degradate of Acephate) aggregate assessment for risks from food, water and residential sources, including the risks posed by methamidophos from the application of acephate, indicates aggregate risks above the Agency's level of concern.

b) Ecological Risks

Risks to bees, birds, aquatic invertebrates, and mammals are high. Acephate and its degradate methamidophos are highly toxic to honey bees and beneficial insects on an acute contact basis.

High acute risks to birds due to degradate methamidophos and high chronic risks are attributed to both acephate and its degradate methamidophos. Laboratory data indicate that acephate causes a reduction on the viability of embryos and chicks, and disruption of migratory patterns; methamidophos causes thinning of the eggshells.

Acephate degradate methamidophos is very highly toxic to freshwater invertebrates on an acute basis. High exposures to acephate in combination with elevated temperatures may cause significant mortalities to estuarine bivalves (clams and oysters). High chronic mammalian risks attributed to the use of acephate, especially from exposure to granular formulations. Incident data indicate that acephate causes plant injury.

1) Profenofos

Use of Profenofos has gone from around 0.35 treatments per acre to 0.06 in 2000, an 83% decline.

a) Human Health Effects

The human health risk for profenofos indicates that there are concerns for occupational mixers and loaders, applicators and flaggers. EPA's assessment indicates concern that crop advisors performing scouting activities could be at risk when spending extended periods in treated cotton fields.

b) Ecological Risks

Profenofos is moderately to highly toxic to birds, highly toxic to bees, and very highly toxic to fish and aquatic organisms. Thirteen separate fish kill incidents implicating profenofos were reported to the agency between 1994 and 1996.

4) Methomyl and Thiodicarb

Thiodicarb rapidly degrades rapidly to methomyl under most conditions. NASS data indicate that Methomyl use has dropped only slightly over the last 5 years, but use had dropped from about 0.38 acre treatments per planted acre to virtually no use in 2000.

a) Human Health Effects

EPA has indicated its concern for occupational exposure and risk to methomyl. Methomyl is an acute toxicity category 1 primary eye irritation. The reentry interval for cotton was 3 days, but was recommended to be reduced to 2 days.

b) Ecological risks

EPA is generally concerned about the ecological effects to terrestrial wildlife and aquatic organisms from the use of these insecticides because most agricultural uses present acute and chronic risks to endangered and non- endangered aquatic organisms.

e. Future Benefits

The adoption of *Bt* cotton has been a clear success story. The exact magnitude of the benefits is not clear. There is reason to expect future benefits will be of the same magnitude as those estimated here. If *Bt* cotton adoption continues to expand worldwide, is likely that benefits will be shifted largely to the consumer in the form of lower prices for cotton products. China, India and Pakistan are major cotton producing countries which account for about 45 percent of world production which when combined with the United States account for about 60 percent of world production (USDA-NASS, Agricultural Statistics 2000). Widespread adoption (similar percent of crop as this country) of *Bt* cotton in these countries should shift a significant portion of benefits to consumers.

6. *Bt* Potato Plant-Incorporated Protectants

This section reviews the benefits from Cry3A protein which controls the Colorado potato beetle. The initial registration for commercial use of Cry3A expressed in potatoes was in May 1995 following a meeting on March 1995 in which the SAP supported EPA's risk and benefit assessments. In November of 1998, EPA approved the use of a plant-incorporated protectant to control potato leaf roll virus. This new registration is expected to increase the benefits for Cry3A when the two plant-incorporated protectants are "stacked" in the potato.

a. Insecticide Usage to Control Colorado Potato Beetle

The majority of potatoes are planted for fall harvesting. Total revenues for 2000 were $2.5 billion for an average receipts of $2,068 per acre (NASS, 1999 and 2000).

Table E. 16. US Potato Production

	Acres Planted in 000's		Acres Harvested in 000's		Yield in CWT	
	1999	2000	1999	2000	1999	2000
Winter	18	17	18	17	229	278
Spring	87	82	85	80	300	281
Summer	69	65	64	63	295	289
Fall	1,203	1,224	1,166	1,200	369	393

Total	1,377	1,388	1,332	1,360	359	382

The Colorado potato beetle is the most damaging pest to potatoes in the United States, although it is not the most damaging pest in all potato growing states. The National Potato Council (1998) identified the Colorado potato beetle as the most important insect pest of potatoes for seven of the top eleven potato producing states.

The adoption of *Bt* potato plant-incorporated protectants has not been as large as it has been for other *Bt* plant-incorporated protectants. In 1996 approximately 10,000 acres or 1% of the total of the potato crop was *Bt* potatoes. Levels of adoption have increased over the last five years up to 50,000 acres or just under 4% of the total 1999 potato crop. Initially only one potato variety was engineered to produce Cry3A but now four varieties, Russet Burbank, Superior, Shepody and Atlantic *Bt,* are available.

Chemical insecticides have a long history of use to control Colorado potato beetles. Thirty-four percent of total insecticide use on potatoes is for control of Colorado potato beetles, more than for any other insect pest (Doane Marketing Research, 1998). There are a variety of alternative materials available to control Colorado potato beetles including some *Bt* microbial pesticide products. The National Potato Council (1998) lists aldicarb, azinphos-methyl, carbofuran, cryolite, disulfoton, endosulfan, esfenvalerate, imidacloprid, metamidophos, permethrin, phorate, and phosmet, as well as *Bt* microbial sprays and *Bt* potatoes, as pesticides to control Colorado potato beetles. In addition, there are several mechanical and cultural controls used to reduce populations of this pest.

b. Grower Benefits

Bt potato (trade name NewLeaf) technology fee was about $30 per acre in 1998 (Gianessi and Carpenter, 1999) and market share was 4%. Savings on the cost of treatment could be as high as $60/acre if one at-plant insecticide application was not needed (Gianessi and Carpenter, 1999). A simple simulation model based on the estimated demand curve or *Bt* potato shows an upper limit benefit for the *Bt* potato of $60 /acre, with a *Bt* seed premium of $30/acre, a market share of 4.0 %. Upper limit *Bt* specific costs are $175/acre and a net benefit per acre of $9.30. (or 8.8% of the $2,021 average potato value per acre). At an average cost of $22/acre (Doane 1998), average acre treatment reductions are the benefits per acre plus seed premium divided by the cost per acre (39.30 / 22 = 1.8). National use reductions are estimated as 89,000 less acre treatments.

c. Environmental Benefits of *Bt* potatoes

Environmental and human health benefits can also be attributed to cases where more toxic insecticides are replaced by *Bt* potato plant-incorporated protectants. Several of the above list of pesticides are organophosphates, carbamates, and synthetic pyrethroids with potential or known adverse effects to non-target organisms and workers. *Bt* plant-incorporated protectants fit well into IPM programs as well as reducing reliance on chemical pesticides.

Significant reduction in toxic insecticide use can also occur with *Bt* potatoes by directly substituting for colorado potato beetle control, and indirectly by enhancing the conservation of natural enemies that can play a role in reducing secondary non target populations. It could also delay the onset of resistance to imidacloprid, which is a highly effective insecticide currently used to control the colorado potato beetle (Dively, 2000).

d. Future Benefits

The adoption of *Bt* potatoes has been limited. However, it has been discussed above that this technology has been moved to a wider range of potato varieties. This should encourage adoption of the technology on a more widespread basis which should increase benefits.

7. Summary of Results

a. General Findings

EPA believes that significant benefits accrue to growers, the public, and the environment from the availability and use of certain *Bt* plant-incorporated protectants. Direct benefits to growers for all *Bt* products is estimated to be less than $350 million in 2000. Indirect or environmental benefits occur as improved pest resistance decreases corn diseases that result from insect interactions. Insect pests that damage ears, kernels or stalks are causative agents for mycotoxin development by carrying fungal spores to the surfaces of damaged kernels and by creating entry wounds on the plant. Common mycotoxins on corn are fumonisins and aflatoxins. Fumonisins are toxic to livestock, especially horses, swine, and cattle; and are carcinogenic to humans and animals. Aflatoxins are known carcinogens to laboratory animals and presumably man. Growers must accept lower prices if mycotoxin levels exceed FDA food standards or total loss if the lower feed standards are not met. The public costs of mycotoxins to human health has not been quantified due to the difficulty of extrapolating from available epidemiological studies.

Cotton has experienced a very large reduction in conventional insecticide usage, a two thirds decrease for the most toxic products to birds and fish, and a one third decrease for the most toxic products to humans. Bird counts in selected cotton producing states have increased, and are positively correlated with *Bt* adoption rates, reductions in insecticide use, and the relative presence of the specie in cotton fields. Aquatic wildlife populations may also benefit. One study indicated that *Bt* cotton helps reduce insecticide runoff. Agricultural workers and people living near cotton fields have benefitted from less chance of accidental exposures to very toxic insecticides. *Bt* corn increases yield and reduces insect damage which can lead to the formation of mycotoxins. *Bt* corn benefits the public by reducing associated mycotoxin health risks to humans and livestock.

These analyses have examined benefits for the past three years. It is expected these benefits will continue in the future and that benefits for *Bt* sweet corn and *Bt* potatoes will increase over time.

b. *Bt* Corn

There are several *Bt* corn plant-incorporated protectant products registered by three basic registrants with more than 19 million acres planted to *Bt* corn. The per acre benefits are modest but there are a large number of acres where the only control before *Bt* corn was a hybrid with corn stalks with some resistance to corn borers. *Bt* corn provides season long control and became a viable control. Annual benefits are estimated to be up to $220 million.

c. *Bt* Cotton

The *Bt* cotton plant-incorporated protectant was registered in 1995 and the market has grown to some 4.4 million acres. Annual benefits are estimated to be up to $160 million. Large reductions in usage of conventional pesticides occurred when the boll weevil eradication program and adoption of *Bt* cotton occurred during the same time period.

d. *Bt* Potato

Bt potato plant-incorporated protectant was registered in 1995, but the market share has remained low, even though the Colorado potato beetle accounts for a third of insecticide use. Like *Bt* sweet corn, the major benefit is a reduction in chemical applications.

About 80% of current insecticides used on potatoes comes from older OP's, carbamates and pyrethroids. Recently registered safer alternatives (Imidocloprid and Spinosad) accounted for 15% of applications. These competitive products may explain the slow adoption of *Bt* potato plant-incorporated protectants, but there may be additional reasons not identified in this review.

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