E. Benefits Assessment

1. Introduction

EPA conducted benefits assessment for the *Bt* plant-pesticides prior to their registrations. For *Bt* corn products, the major benefits predicted were an increase in yield and for *Bt* cotton and *Bt* potatoes, the major benefits predicted were a reduction in the use of chemical insecticides. The information available to the Agency confirms that these general predictions were accurate. Most farmers growing field corn in the United States do not use chemical insecticides to control the target pests (typical range is 5 to 10 % of field corn acres with average about 8%) 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, however, since it is across the 70 to 80 million acres of corn grown in the United States each year. Farmers growing *Bt* corn who were not using chemical insecticides have seen increased yields in areas where infestations of European corn borer (ECB) 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 is far less than that in the other crops. A variety of reasons are likely to be responsible including the introduction of a new, highly effective chemical insecticide.

Although farmers pay a premium to use *Bt* plant-pesticide 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 unexpected low. Another example is when cotton growers face unexpected high pest pressure (such as tarnish plant bug which is not controlled by Cry proteins) and the savings on reduced chemical use never materializes.

2. Review Methodology

a. Scope of Review

Although registrations were approved in 1995 for *Bt* plant-pesticides in potatoes, corn, and cotton, very limited use if any, occurred that year. This report reviews environmental and grower benefits for the 1996 to 1999 period. No projections for future years are made. The economic analysis does not address the effects on commodity prices, shifts in benefits among producers and consumers, impacts on foreign trade, registrant profitability and the incentives for product development.

b. Sources

The methodology to estimate reductions in pesticide use has relied upon USDA National Agricultural Statistical Service (NASS) publicly available pesticide use surveys. Field crops have annual data from 1991 thru 1999, while vegetables surveys (sweet corn) are bi-annual. The review has examined trends in acre treatments with respect to how adoption rates affect the chemical insecticides that control the same pests as the *Bt* plant-pesticides as well as overall pesticide use. The limitations of the NASS data are that target pest information is not gathered and selected States may change from year to year. The Environmental Protection Agency also relied upon some information from the Doane Marketing Research, Inc. which is proprietary market research data. Target pest data is presented sparingly in this report, only to reinforce the validity of the conclusions made using the publicly available NASS data.

c. Grower and Environmental Benefits

Grower benefits reflect the value of *Bt* plant-pesticides to growers on account of anticipated higher yields, lower input costs, less financial risk, or any other factor that the grower considers when selecting the *Bt* plant-pesticides over alternative seed. Grower benefits are measured by the willingness to pay (similar to a demand curve). Net benefits are the difference between absolute benefits and the price premium paid for the *Bt* seed. Net benefits must be positive (assuming profit maximization and perfect information) by definition. A grower may not recover the cost of a pesticide application, such as a preventative treatment and the pest never appears. Insurance is a good analogy. The anticipated benefits of insurance are related to the risk of loss, but one doesn't buy insurance unless the value of risk mitigation exceeds the premium paid.

Environmental benefits refer to the indirect positive environmental or human health effects that benefit society as a whole, but are not captured in direct costs or returns. Examples of environmental benefits may include less worker exposure to chemical insecticides, less ground and surface water contamination, and less impacts on non-target wildlife. A standard objective in cost/benefit analysis is to estimate the value of both. But estimating the value of environmental and human health benefits has not reached consensus for many environmental issues. The range of benefit projections are often too wide for meaningful interpretation. This review uses a more qualitative approach to characterize benefits.

Grower benefits of *Bt* crops have been extensively studied. Some studies have used traditional pesticide benefit methodologies in which the analyses are based on comparing the pest control method to the alternatives, relying on comparative performance studies and pesticide costs. Other studies have used survey data to formulate willingness to pay demand curves, and econometric analyses to identify yield and producer cost differences for *Bt* adopters versus non-adopters.

For this review, EPA developed a simple model that forces consistency in the estimation of benefits, costs and market share. The EPA model assumes the selection decision to adopt *Bt* plant-pesticides is based on profit maximization, when the anticipated benefits exceed the costs.

Anticipated benefits increase expected profits through higher yields and lower insecticide use.

The decision to select *Bt* plant-pesticide seed occurs when anticipated benefits exceed not only the seed premiums but other costs associated with the seed, such as yield differences between non *Bt* hybrids, resistance management requirements, export restrictions on GM foods, etc. The simple model requires only the upper limits for benefits and costs since random draws are selected from a uniform probability distribution (an equal probability of selection for any value between zero and the upper limit.) Market share is based on the frequency of selection, and average net benefits are derived from each positive selection.

The assumption of a uniform probability distribution is a simple approximation to a complex problem. The one parameter in a uniform probability distribution determines both the mean and standard deviation A sensitivity analysis was conducted to test the importance of distribution assumptions on the benefit estimate. It turns out that changes in the estimate of variance is much more important that distribution assumptions (uniform vs normal). Examples of factors that influence variance are the variability in pest pressure among regions, variability in anticipated comparative performance, and variability in cropping practices.

The inputs to the simple simulation model are:

1. Seed premium,
2. Upper limit benefit of the *Bt* plant-pesticide,
3. Upper limit cost of the *Bt* plant-pesticide.

The outputs are:

1. Percent frequency of selection (market share), and
2. Distribution of net benefits.

Upper limit estimates for benefits are derived from claims made by registrants as well as independent studies. Seed premiums are also known. The upper limit for other *Bt* associated costs is derived indirectly. Given values for all seed premium and upper limit benefits, only one value for costs will equate model market share output to actual market share.

3. *Bt* Corn Plant-pesticides

The major pest controlled by *Bt* corn is the European corn borer. Other important insects controlled are corn earworm, southwestern corn borer, and other stalk boring insects.

a. The adoption of *Bt* plant-pesticides in corn has lived up to expectations. Typically EPA would estimate that adoption of a new pest control product would reflect a gradual increase as the more innovative farmers try the new product first and determine how to successfully fit the new product into their farming practices. However, in this case, EPA did anticipate that eventually *Bt* corn might exceed the use of chemical insecticides for ECB and other target pests because it was known that application problems such as appropriate timing made the use of these chemical alternatives difficult. But the speed of adoption was faster than expected. Farmers often accepted lost yields rather than incur the expense of the chemical insecticides where it was unclear the pesticide use was worth the expense. *Bt* corn use has exceeded 20% of field corn acreage where chemical insecticide use to control ECB rarely if ever exceeded 10%. EPA estimates adoption at 0.4 million acres (1%) in 1996, 4.4 million acres (6%) in 1997, 14.4 million acres (18%) in 1998, and 19.7 million acres (26%) in 1999. USDA has estimated that use of *Bt* corn in the 2000 season may be lower than 1999. Reasons may include the public discussion regarding agricultural biotechnology and some companies' reluctance to buy *Bt* corn, low corn prices, and/or low insect infestations.

b. Estimating Reductions in Pesticide Use

The National Center for Food and Agricultural Policy (Gianessi and Carpenter, 1999) used USDA's NASS annual surveys of major producing corn states to identify trends in use reduction, from 1994 to 1998. A similar methodology is used in this review, with an extended time period (1991 to 1999), dividing states in high and low adopters, and including all insecticides as well as those recommended for European corn borer. The hypothesis is that use reduction is more pronounced in states with high adoption rates and more pronounced for the other insecticides used to control ECB. The analysis is limited to the 6 states for which annual chemical usage on corn is provided in each year from 1991 to 1999. The states are divided into two groups- the high adopters and low adopters.

State	Acres Grown (Millions)	Adoption rate (1999)
Iowa	12.5	36%
Illinois	10.5	31%
Nebraska	8.6	33%
Missouri	2.7	25%
Total (High)	34.3	33%
Indiana	5.7	10%
Wisconsin	3.5	10%
Total (Low)	9.2	10%

Source: NASS and registrant annual submissions of planted acreage

Individual chemical insecticides were also divided into two groups--ones that are used for the control of European Corn Borer (ECB) and those that are not, based on State recommendations.

Acre treatments for insecticides recommended for ECB have declined from 8% in the 3 years prior to the introduction of *Bt* corn (1992 to 1995) to 5% in 1999, measured with respect to acres planted. Most of the reduction is with Chlorpyrifos and Methyl Parathion. It should be noted that 1998 had very low ECB pest pressure (Marlin Rice, personal communication 8-31-00). There is no apparent trend for all corn insecticides.

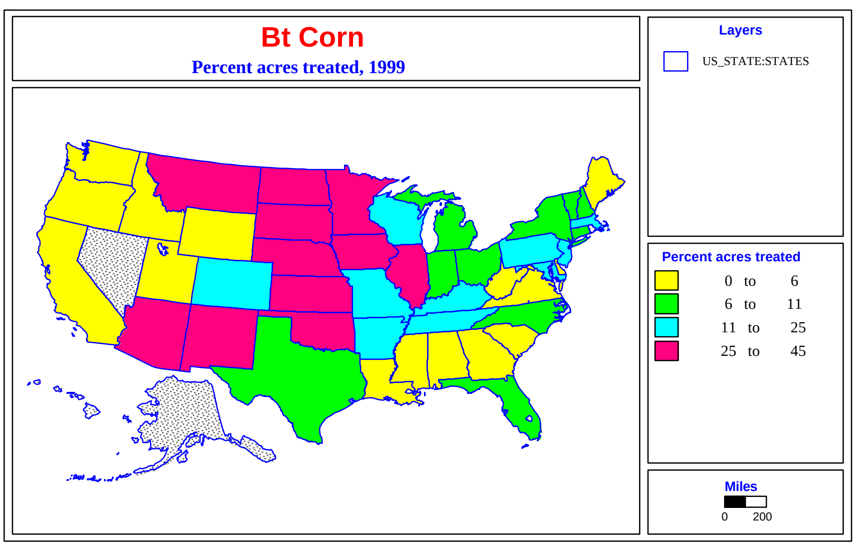
Insecticides Recommended for European Corn Borer
Acre treatments as a fraction of acres planted*

	1992 to 1995	1996	1997	1998	1999
Chlorpyrifos	8%	8%	8%	7%	5%
Permethrin	3%	2%	4%	2%	2%
Methyl parathion	2%	2%	0%	0%	1%
Lambda-cyhalothrin		1%	0%	1%	2%
All ECB controls	13%	13%	13%	11%	11%
All corn insecticides	29%	24%	29%	32%	32%

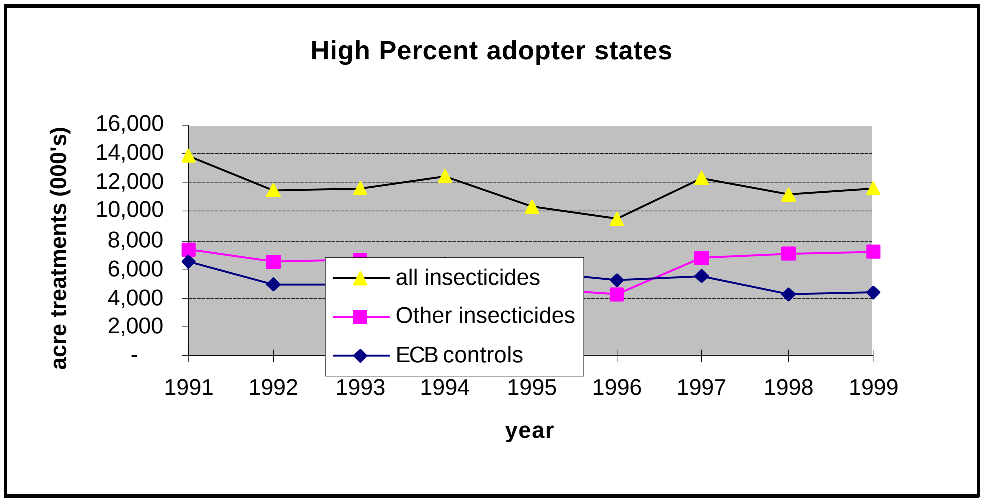
* Note: some acres may be treated multiple times

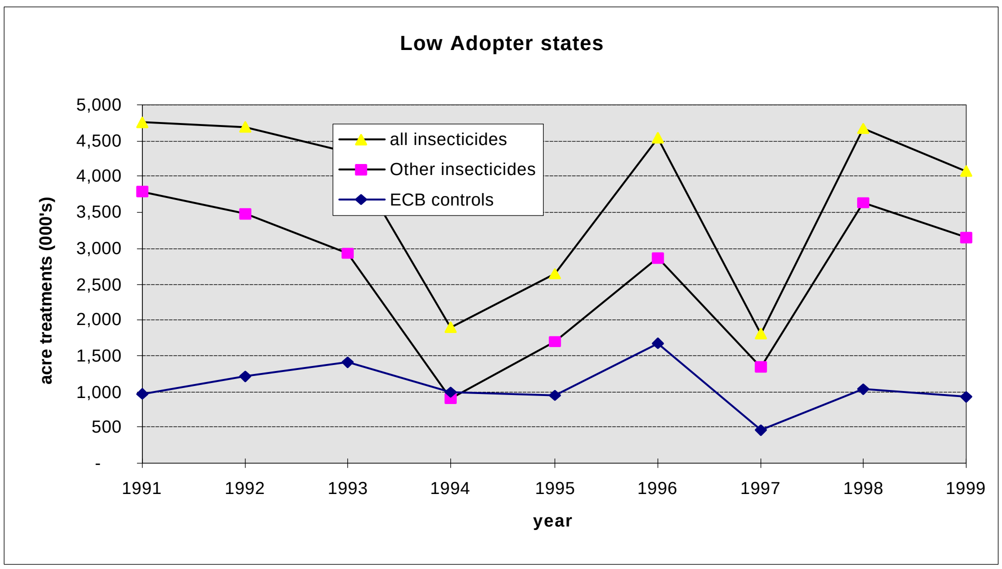
As expected, in high percent adoption states, since Bt corn plant-pesticides were introduced into the market place, there is a reduction in use for those pesticides recommended for ECB control, from 6 million to slightly over 4 million acre treatments in 1999, a reduction of about one-third. But the aggregate acre treatments for all insecticides do not show a decline. As expected for low percent adopter states, neither the ECB pesticides or total insecticides show a reduction in acre treatments. It is beyond the scope of this analysis to explain why overall insecticide use has not dropped.

Percent of Acres Planted in 1999 with *Bt* corn.



Sources: USDA data on acres planted and registrant data combined for *Bt* corn.





Source: Agricultural Pesticide Use on Field Crops, NASS, 1991 thru 1999

The extent to which ECB's are secondary pests will lower the impact of *Bt* corn on use reduction, and the low infestation years in 1998 and 1999 may have made ECB a secondary pest more often. High adoption states are also high corn root worm states, and the portion for ECB is a minor fraction of total use.

C. Grower Benefit Analysis

The economics of *Bt* corn benefits have been studied extensively. Summarizing the research, ECBs cause significant yield loss but infestation levels and resulting loss are inconsistent from year to year, and therefore, an investment in *Bt*-corn is an economic risk. The premium paid for *Bt*-corn seed will likely only be returned in years when corn borer infestations are moderate to heavy. A matrix showing the returns based on the number of corn borers per plants, corn prices, and yield before loss is shown below, assuming *Bt* corn costs $10 per acre, each corn borer reduces yields by 5 percent and *Bt* corn provides 100 percent control. Economic threshold for the use of *Bt* corn is anytime there is one or more ECB per plant. The yield benefits of *Bt* corn are reduced as the corn price per bushel decreases. Declining corn prices to sub $2.00/ bushel levels since 1998 along with low pest pressure have reduced the benefits of *Bt* corn.

Projected return per acre in $ with *Bt* corn.

		corn borers per plant				
Yield in bus	Corn price/ bu	0	0.5	1	1.5	2
125	$2.50	-10	(2.19)	5.63	13.44	21.25
	$3.00	-10	(0.63)	8.75	18.13	27.50
150	$2.50	-10	(0.63)	8.75	18.13	27.50
	$3.00	-10	1.25	12.50	23.75	35.00
175	$2.50	-10	0.94	11.88	22.82	33.75
	$3.00	-10	3.13	16.25	29.38	42.50

Source: Marlin Rice, Iowa State University Extension, 1997.

Gianessi and Carpenter (1999) estimate average net benefits at a plus $18.43/acre in 1997 (a year of high infestation) to a loss of $1.81/acre in 1998 (a year with low infestation and low corn prices). Total net benefits are a $72 million gain in 1997 to a $26 million loss in 1998. (Note that this report computes benefits at a point in time after the growing season ends. This definition is different from benefits timed at the decision to select seed. Over many years, anticipated benefits would equal actual benefits).

The Agency's simple simulation model predicts a 25% nationwide adoption rate based on a *Bt* seed premium of $10/acre, upper limit benefits are $20/acre (2 corn borers per plant, 175 bu/acre, $1.75 price/bushel), and upper limit costs of $10 per acre. These costs relate to additional grower burdens for insect resistance management, lower seed yields than other hybrids, or any other cost burden specific to *Bt* adopters. The average net benefit of $3.31 per acre on 19.755 million acres of *Bt* corn planted in 1999 leads to the national estimate of $65.4 million.