The Farm-Level Economic Impacts of *Bt* Corn From 1996 through 2001:

An Independent National Assessment

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Executive Summary

Corn farmers have now planted over 70 million acres of *Bt* corn, genetically engineered to express *Bacillus Thuringiensis* (*Bt*) toxins in plant tissues for the control of two Lepidopteran insects, the European Corn Borer (ECB) and the Southwestern Corn Borer (SWCB). Farmers pay a significant premium for *Bt* corn varieties. But do increased yield benefits justify the added expenditure?

From 1996-2001, American farmers paid at least $659 million in price premiums to plant *Bt* corn, while boosting yields by an estimated 276 million bushels. The increased production earned farmers about $567 million, for a net loss of $92 million – about $1.31 per acre planted to *Bt* varieties.

For each farm, the economics will differ depending upon the frequency of ECB/SWCB infestations, how widely the insects occur, insect population dynamics throughout their multi-stage lifecycle, and a host of biotic (natural predators and corn plant defenses) and abiotic (cold weather and hard rains) factors. In this report, the first independent national evaluation of farm-level economic impacts, these factors are integrated in a model projecting yield increases on acres planted to *Bt* corn for the major corn producing states for 1996-2001 (see Table 23). Our method and assumptions are purposefully conservative in order to not underestimate the value of *Bt* corn.

One surprising finding emerges – the price of *Bt* seed can vary greatly. Some farmers have been paying a premium as high as $30.00 per acre for *Bt* corn (far more than the $8.00 to $10.00 "technology fee" typically charged) while other farmers receive discounts or price breaks that trim the *Bt* corn price premium to just a few dollars per acre. In some cases *Bt* corn seed is actually cheaper than several top-yielding conventional varieties.

The linkage between seed price and yield performance is hit-and-miss, especially in years or regions where ECB/SWCB populations do little or no appreciable damage to corn plants. Between the impact of varietal choice on yields and differences in seed costs, the selection of corn seed can and routinely does shift profits up or down by $20 to $40 per acre, and sometimes by $50 or more per acre.

The investment in *Bt* corn has, on average, paid off for farmers in three years (1996, 1997 and 2001), yet it has resulted in losses in another three (1998, 1999, and 2000). It appears that *Bt* corn delivered the greatest net benefits in 2001, due largely to increased infestations of ECB/SWCB, but the 2001 data are preliminary. Other key findings are that:

- The cash outlay for seed for a field where farmers decide to plant a *Bt* corn hybrid is about 30 to 35 percent higher than the cost of otherwise well-adapted conventional varieties. **This increase in per acre seed expenditures is by far the biggest in history linked to a single new trait.**

- On average farmers have harvested 3.9 more bushels per acre planted to *Bt* corn.

- Farmers who know and understand corn borer population dynamics can almost surely find ways to more profitably deal with ECB/SWB pressure than planting most of their acreage every year to *Bt* corn.

In making seed choices, farmers should be guided by several factors and findings:

- The newest and most expensive varieties may *not* be the most likely to produce the highest yields, nor do lower-cost varieties lack the genetics to produce top yields.

- Well-tested, proven hybrids with traits matched to local soil, climate and agronomic conditions offer the least risk.

- Seed bargains will help maximize per acre profits, not yields. The quest for county yield records may come at the expense of profit margins.

- New *Bt* varieties should be tested in small, representative production fields alongside closely matched conventional varieties, or in required non-*Bt* corn refuge acres, to evaluate how well each does under various circumstances.

Farmers should also remember that *Bt* corn is no different than other new technologies that increase production. The 276 million more bushels of corn moving through markets in 1996-2001 have had a ripple effect through the farm economy, marginally reducing the average price received by all farmers growing corn. International concern and controversy over *Bt* corn has also reduced export sales by hundreds of millions of bushels, increasing supplies in the U.S. and further decreasing prices from the levels they otherwise would have attained.

Six years is too short a period to take the full measure of any major new agricultural technology, especially one as novel and contentious as *Bt* corn. In all likelihood the farm sector will learn how to make more effective use of this technology and over time the price premium should narrow. The performance of *Bt* hybrids is also likely to improve as more backcrosses are made and experience is gained with transformed varieties. However, it remains to be seen whether resistance can be prevented in corn borer populations and whether physiological or soil microbial community problems will surface. No one can predict, either, whether world markets will warm to *Bt* corn.

Hopefully, lessons learned in the commercial introduction and planting of today's *Bt* varieties will help breeders develop the next generation of insect-resistant corn. Farmers, in particular, should pay closer attention to whether the next wave of "advanced" corn genetics is likely, in the end, to improve their profitability or shave another slice off per acre profit margins.

I. Impacts of *Bt* Corn on Farm Seed Expenditures

Corn hybrids genetically engineered to express *Bacillus Thuringiensis* (*Bt*) toxins were developed in the 1980s and commercially introduced in the mid-1990s. The first regulatory approvals were granted in 1992-1993, allowing limited experimental plantings. Significant acreage of *Bt* corn varieties was planted in 1996, the first year included in this analysis.

A thorough review of the history of *Bt* corn and the risks and benefits associated with this technology is contained in the documents prepared by the U.S. Environmental Protection Agency as part of its 2000-2001 reregistration of plant varieties genetically engineered to express *Bt* toxins. See Appendix 1 for an overview of EPA documents accessible on the agency's website, as well as comments prepared by private organizations on key reregistration issues including management of resistance, impacts on nontarget organisms, particularly Monarch butterflies, and the benefits of *Bt* corn.

This report provides the first in depth, independent economic assessment of the impact of *Bt* corn on farmer seed expenditures, corn yields, and grower profits. To date, national-level benefit assessments of *Bt* corn have been little more than educated guesses based on simple models and questionable assumptions. The EPA's final *Bt* corn benefits assessment is, for example, remarkably simplistic, especially in light of the time and resources spent in carrying it out.

The agency projected total grower benefits for 1998-2000 based on two scenarios – low insect pressure and high insect pressure. According to EPA, farmers planting *Bt* corn in years of low pressure gained $2.11 per acre in average net benefits and $12.21 under high population pressure. These estimates were, in turn, basically assumptions – that *Bt* corn yields on acres facing low ECB pressure have averaged 5.4 percent higher than similar fields planted to conventional varieties, and that yields have been 10.81 percent higher in the high pest pressure scenario.

These key assumptions regarding the average impact of *Bt* corn varieties on yields under low and high ECB pressure are attributed by EPA, incredibly, to a short North Carolina University article published in 1998 (Carlson et al., 1998). The yield estimates in this study rested upon the very limited field data on *Bt* corn yields available at the end of the 1996 crop season. The EPA's benefit assessment also sites reports on *Bt* corn benefits carried out by the National Center for Food and Agricultural Policy (NCFAP) (Carpenter and Gianessi, 1999 and 2000), but the agency notes that the North Carolina and NCFAP studies "both used essentially the same information about yield advantages due to reduced insect damage, technology fee and reductions in conventional pesticide use" (page IIE3, EPA, 2001a).

In 1995-1996 University of Wisconsin agronomists carried out carefully designed comparative yield trials spanning several locations in the state (Lauer and Wedberg, 1999). They measured yields for a group of *Bt* hybrids in contrast to closely matched isolines (varieties that genetically match *Bt* varieties except they do not contain the *Bt* gene), and "standard" high yielding varieties commonly chosen by farmers in the areas where the experimental plots were located. Yields were measured reflecting three scenarios –

- "Natural infestations" (in 1995, a "severe" second generation ECB infestation occurred statewide, and in 1996 a "severe" first generation outbreak was reported);
- Corn plants were inoculated with 100 egg masses per plant four times in the growing season, to simulate high-insect pressure; and
- Standard insecticide treatments.

Averaged across all locations the "standard" non-*Bt* hybrids and the *Bt* hybrids yielded 158 bushels under "natural infestations" (labeled by the researchers as "severe" for one generation of ECB in each year). The insecticide treated plots were a control, intended to isolate the impact of the *Bt* gene. In 1996 the yield of the standard hybrids was 12 bushels per acre greater than the *Bt* hybrids in the insecticide treated blocks, suggestive of a yield drag in *Bt* corn.

But when the standard hybrids had to contend with both the ECBs from the natural infestation plus the inoculation with ECB egg masses, yields dropped 4 percent to 8 percent. This important, widely cited experiment reinforces the conclusion that the EPA and NCFAP estimates of ECB yield losses under "low" and "high" infestations are actually more closely associated with losses under high and very high populations, levels which occur perhaps once, or at most twice a decade in most Corn Belt states.

These assumptions are clearly contradicted by reams of data on ECB population levels from major corn producing states. Section II provides state-by-state summaries of ECB levels and corn injury estimates. While it is true that ECB populations reach damaging levels in one or two years in a decade, it is also true that they cause no appreciable impacts on yields in five or more years in the average decade, a fact the EPA ignores in its benefits assessment.

A. Acres Planted to *Bt* Corn Hybrids in 1996-2001

There are several sources of information on the acres planted to *Bt* corn since 1996, although publicly available data are scant. The best and most extensive data are compiled by the Agricultural Biotechnology Stewardship Council on behalf of the industry and cover the acres planted to various *Bt* varieties by state and nationally. These data have been submitted to EPA but are regarded as "Confidential Business Information." Hence, the EPA has published only very general aggregate data on acres planted by state and nationwide in its benefit assessments and other public documents.

The USDA has published estimates of the acreage planted to *Bt* corn, drawing on various surveys of corn producers carried out by the National Agricultural Statistics

Service (see Appendix 1 for details). The Department has recently released state-by-state data on the percent of corn acres planted to *Bt* varieties for 2000 and 2001.

A variety of private companies collect data on the corn seed market. Doane Marketing Research, Inc. carries out by far the most extensive survey of farmer seed purchasing decisions. The Doane corn seed survey is "the most comprehensive source of corn seed industry information available on a syndicated basis" (Doane Marketing Research, 2000). It is based on a survey of 4,601 farmers, heavily weighted toward larger operations in key corn producing states (see Appendix 1 for more on the Doane data and survey).

Doane Data Provides Key New Insights

Benbrook Consulting Services (BCS) purchased basic information on the corn seed market for 1998-2000 from Doane Marketing. Access to the data is granted under a license, which precludes release of the raw data or disclosure of information that would make it possible to reconstruct the raw data on specific varieties. These data are by far the most detailed available from any source on the price and marketshare of specific corn varieties. Access to these data makes possible the first independent estimates of the market for *Bt* corn, including the magnitude of the premium charged for *Bt* varieties compared to conventional varieties.

The Doane Marketing data supplied to BCS are reported by company, variety, type of variety, and Doane "Maturity Group". (Doane analysts classify all corn varieties into one of 11 "Maturity Groups" based on relative maturity ratings). The fields of Doane data purchased by BCS include acres planted, units planted, average retail price, average discount, and net price (retail price minus discounts). The three years of corn seed data encompass 19,710 records, each representing a specific variety sold in one of the three years.

Over this period, there were 15,384 conventional varieties offered for sale and 2,320 *Bt* corn hybrids engineered for protection against the European Corn Borer (ECB). Accordingly, on average there were 6.6 conventional varieties on the market for each *Bt* hybrid marketed over this period. In addition, there were –

- 232 varieties on the market with "stacked" *Bt* and herbicide tolerant traits,
- 975 varieties engineered for resistance to imidazolinone herbicides,
- 242 resistant to Liberty (glufosinate) herbicide,
- 23 resistant to Poast (sethoxydim) herbicide, and
- 534 resistant to Roundup (glyphosate) herbicide.

Table 1 provides an overview of published EPA, USDA, industry, and private estimates of the percent of total national corn acres planted to *Bt* varieties for 1996 through 2001. By all accounts, acreage planted rose sharply from crop season 1997 through crop year 1999 and has declined moderately in the last two years.

Table 1. Estimates of the Acreage Planted to *Bt* Corn Varieties, 1996-2001						
	Percent National Acres Planted					
Source of Estimate	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
USDA	1.4	7.6	19.1		18	18
EPA	1	6	18.1	25.6	24.5	
Ag Biotech Stewardship Council			18.1	25.6	24.5	
NCFAP	1	6	18	26	19	

Sources: USDA 2001 *Bt* corn acres from USDA/NASS Agricultural Statistics Board, Crop Acreage Report released June 29, 2001; 1996-1999 data from "Genetically Engineered Crops for Pest Management in U.S. Agriculture: Farm Level Effects" (Fernandez-Cornejo and McBride, 2000).

EPA data for 1998-2000 calculated from Agricultural Biotechnology Stewardship Council sales reports (EPA, 2001a); and from USDA/EPA Position Paper on Insect Resistance Management in *Bt* Crops, Office of Pesticide Programs 5/27/99.

NCFAP data from Gianessi and Carpenter, 2001.

Detailed data on acres planted to specific varieties from Doane Marketing Research has been analyzed for crop years 1998-2000. Table 2 reports the acres planted and units sold by type of variety. The table also reports the average number of acres planted per "unit" of corn seed. A "unit" of corn seed is a bag containing approximately 80,000 seeds. The last column in Table 2 estimates the average planting rates (corn seeds per acre) by type of corn hybrid. The estimates are based on the acres planted and the number of 80,000 seed units sold. Note that *Bt* hybrids appear to be planted at a somewhat higher rate per acre, especially in contrast to Roundup Ready varieties.

Key summary information on the size of the corn seed industry, acres planted by year to *Bt* and conventional varieties, and the value of the corn crop is presented in Table 3. The acres planted to *Bt* varieties reflects a "best estimate" drawing on all sources of data covered in Tables 1 and 2. The data in Table 3 is used throughout this report in estimating the total size of the *Bt* corn premium and in comparing the costs of *Bt* corn to the benefits received by farmers.

Table 2. Overview of the Corn Seed Market by Type of Hybrid Based on Doane Marketing Research, Inc. Data, 1998-2000 [See notes]

Year	Type of Variety	Acres Planted	Units Sold	Acres Planted per Unit Sold	Planting Rate (Seeds per Acre)
1998	*Bt*	13,908,962	4,869,464	2.86	28,008
	Conventional	62,536,643	20,820,118	3.00	26,634
	Herbicide Tolerant	3,755,065	1,275,991	2.94	27,184
	Roundup Ready	597,539	192,407	3.11	25,760
	All Varieties	80,798,209	27,157,980	2.98	26,890
1999	*Bt*	16,209,728	5,713,267	2.84	28,197
	Conventional	55,763,994	19,091,383	2.92	27,389
	Herbicide Tolerant	3,709,120	1,291,377	2.87	27,853
	Roundup Ready	1,928,369	628,528	3.07	26,075
	All Varieties	77,611,211	26,724,555	2.90	27,547
2000	*Bt*	16,941,711	5,972,903	2.84	28,204
	Conventional	55,285,919	19,216,886	2.88	27,807
	Herbicide Tolerant	4,657,523	1,630,054	2.86	27,999
	Roundup Ready	2,693,903	872,872	3.09	25,921
	All Varieties	79,579,056	27,692,715	2.87	27,839

Notes: *Bt* acres planted and units sold include stacked varieties expressing both the *Bt* and herbicide tolerant traits.

Source: Benbrook Consulting Services, based on Doane Marketing Research, Inc. corn seed surveys.

Table 3. Overview of the Corn Acres Planted, *Bt* Acres Planted, Yields, and Production at the National Level, 1996-2001

	1996	1997	1998	1999	2000	2001
Total Acres Planted (1,000 acres)	79,229	79,537	80,165	77,386	79,545	76,109
Percent Acres Planted to *Bt* Varieties*	1.4%	7.6%	17.2%	20.9%	21.3%	20.0%
Acres Planted to *Bt* Varieties (1,000 acres)	1,109	6,045	13,788	16,174	16,943	15,222
Average Yields (bushels/acre)	127.1	126.7	134.4	133.8	137.1	136.3
Average Corn Market Price (dollars/bushel)	$ 2.71	$ 2.43	$ 1.94	$ 1.82	$ 1.85	$ 2.10

* Percent acres planted to *Bt* varieties includes stacked varieties with *Bt* and herbicide tolerant traits.

Production and price 2001, USDA Supply/Demand report, October 12, 2001; 1996-2000 Acres of *Bt* corn are most likely estimates from Table 1; 2001 *Bt* corn acres from USDA/NASS Agricultural Statistics Board, Acreage report released June 29, 2001.

B. The *Bt* Corn Price Premium

Farmers pay a significant premium for *Bt* corn varieties. The $64,000 question (actually $659 million) is whether the benefits of *Bt* corn justify this added expenditure.

The premium price farmers pay for *Bt* corn seed is composed of two components – a technology fee per unit of seed sold and a pure price premium. The “tech fee” is charged by the companies holding patents over *Bt* genetic engineering transformation technology and is part of the licensing agreements between the patent holders and the seed companies incorporating the gene in their varieties. Typically, this tech fee is then passed on to farmers through higher prices per unit of seed, although some companies have chosen to increase their prices by an amount greater than the tech fee, while others have not raised their prices enough to cover the standard industry-wide tech fee. It is likely that some companies have negotiated more favorable deals than others in gaining access to the technology. One company – Aventis Crop Sciences, the source of StarLink corn that contains the *Bt* gene and is also resistant to Aventis’s Liberty (glufosinate) herbicide – does not charge a tech fee for its *Bt* trait and instead profits from increased sales of Liberty herbicide.

In its benefits assessment, the EPA assumed an $8.00 per acre premium composed entirely of the technology fee. Gianessi and Carpenter (2001), in their analyses of *Bt* corn benefits, assume an average price premium of about $10.00 per acre in 1997 and

1998, and about $8.00 per acre in 1999 and 2000. These estimates suggest a technology fee between $24.00 and $30.00 per unit of seed. A variety of news reports, company press releases, and analyses have either announced or estimated the *Bt* corn technology fee. Several sources of such estimates are summarized in Table 4.

Table 4. *Bt* Corn Seed Technology Fees Charged per Unit of Seed Sold and Acre Planted by Company and Year

Company	Year	Tech Fee per Unit	Tech Fee per Acre	Source of Information
Pioneer	1999	$ 26.00	$ 9.09	Cited in Hyde et al., 2000
Monsanto	1999	$ 24.00	$ 8.39	Cited in Gianessi and Carpenter, 1999
Steyer Seeds	2001	$ 30.00	$ 10.49	http://www.steyers.com/price/
Stine Seed	2001	$ 18.50	$ 6.47	http://www.directag.com
Karfoff Seed	2000-2001	$ 24.00	$ 8.39	http://www.karhoffseed.com/seed.html
Industry-wide	1997	$ 30.00	$ 10.49	Gianessi and Carpenter, 2001
	1998	$ 30.00	$ 10.49	
	1999	$ 24.00	$ 8.39	
	2000	$ 24.00	$ 8.39	

Notes: Tech fee per acre assumes 2.86 acres of *Bt* corn planted per unit of seed (seeding rate of 28,008), as estimated in Table 2.

Source: Benbrook Consulting Services, 2001.

One fact is clear. *Bt* corn seed technology fees are in play. They have come down some since 1996-1998 and some companies have announced a change in their pricing structures for crop year 2002. Technology fees will be built into the price of seed at the grower level and not broken out in price sheets and invoices, as often now the case. This will make it harder for farmers (and analysts and regulators) to track changes in tech fee levels, given the many factors triggering shifts in the price of corn seed varieties.

1. Establishing the *Bt* Corn Price Premium

An extensive analysis was carried out using Doane's data to produce an accurate estimate of the total price premium paid for *Bt* corn varieties in contrast to otherwise similar and top-performing conventional varieties, both before and after discounts. Three methods were used to extract insights from the Doane dataset on price premiums.

First, average annual prices were computed for all 17,000 plus conventional and *Bt* varieties across three years within the 11 Doane maturity groups. This computation required several steps. First, the market share of each variety within its maturity group was calculated. For example in 1998, we added together the units of all conventional seed sold that fall in Doane maturity group 1. Then, we calculated for each conventional variety in maturity group 1 its share of total maturity group 1 conventional sales. These weights were then used to calculate weighted average retail prices, discounts, and net prices for all units of conventional seed sold within maturity group 1.

The same procedure was used for *Bt* varieties in maturity group 1, as well as conventional and *Bt* varieties in all of the 11 Doane maturity groups. This analysis produces a table with 66 lines (three years times two types of seed times 11 maturity groups).

This method is more accurate than just simply averaging prices because it places heavier weight on the prices of those varieties accounting for the greatest portion of total sales within a maturity group. These are the varieties, moreover, where the underlying Doane data are probably the most accurate, since these major varieties were planted by many more farmers in the population of growers surveyed by Doanes.

Next, we used the share of total unit sales by maturity group and seed type to produce weighted average prices and discounts per unit sold across the 11 maturity groups. These calculations were done for all conventional and *Bt* varieties in a given year and collapses the 66 lines of data down to 6 – two types of seed in each of three years. The results are reported in Table 5. Stacked varieties containing both *Bt* and herbicide tolerance traits are not included in this analysis.

Table 5. Average Price Premiums for *Bt* Corn Varieties Compared to Conventional Varieties, Weighted by Units Planted, 1998-2000

Year	Type of Variety	Average Retail Price	Average Discount	Average Net Price	Premium per Unit	
					Retail Price	Net Price
1998	Conventional	$86.18	$6.36	$79.81	$ 30.65	$ 27.48
	Bt	$116.83	$9.54	$107.29		
1999	Conventional	$87.34	$7.03	$80.31	$ 27.70	$ 24.11
	Bt	$115.04	$10.61	$104.42		
2000	Conventional	$89.25	$7.25	$82.00	$ 27.31	$ 24.37
	Bt	$116.56	$10.18	$106.37		

Source: Benbrook Consulting Services, based on Doane Marketing Research, Inc. corn seed surveys, 1998-2000.

In 1998 the average price premium between conventional and *Bt* varieties, before any discounts, was $30.65 per unit, or about $10.75 per acre based on 2.86 acres planted per unit of *Bt* seed (see Table 2). Counting discounts for early purchase, volume sales, and bundling, the average net price premium was $27.48, close to the commonly reported size of the technology fee – about $26.00.

The price premium fell modestly in 1999 and has remained, by all accounts, relatively stable since then. In 1999 the average retail price premium was $27.70 and $24.11 in terms of average net price.

The second and third methods used to estimate the *Bt* corn price premium involved comparing the price paid for a *Bt* hybrid to the price paid for an otherwise genetically similar conventional variety sold by the same company. This method depends on two conditions: first, the ability to identify the base genetics of a given *Bt* hybrid offered for sale; and second, that the base-genetics-hybrid is also offered for sale.

In response to requests from farmer-customers and researchers, Pioneer Hi-Bred International reported the base genetics for nearly all its *Bt* hybrids in 1999-2001. The corn variety numbering systems used by DeKalb and a few other companies make it easy to recognize some matches between *Bt* varieties and their base genetics – cases where the letters "*Bt*" are simply added to the conventional variety number. In other cases and for other companies, the morphological and pest resistance characteristics of conventional hybrids in the same maturity group must be reviewed to locate the closest match in terms of comparative relative maturity, stalk strength, ear size, corn plant height, ear length, and resistance to various pests. This method is reliable for identifying conventional varieties that are very similar to *Bt* varieties, but probably misses the true base genetics of *Bt* hybrids in some cases. In comparing the prices of *Bt* and otherwise similar conventional varieties, this caveat is not of major consequence.

Method two compares prices and premiums across 19 pairs of *Bt* and similar conventional hybrids offered for sale by Pioneer Hi-Bred International. Table 6 reports the results and shows an average retail price premium of $32.68 and an average net price premium of $33.57. The difference reflects the fact that price discounts offered on conventional varieties were about 8 percent greater than *Bt* hybrid discounts.

The range of prices is also intriguing. The most expensive *Bt* variety is over $50.00 per unit more expensive than the least expensive *Bt* varieties. This translates into an increase in per acre seed expenditures of about $17.50 per acre; with a net return of $1.75 per added bushel harvested on acres planted to *Bt* varieties, a farmer would need to harvest 10 bushels more per acre to just break even on the purchase of such a *Bt* corn variety.

The price premium for the most expensive *Bt* variety in Table 6 is over $50.00 per unit – composed of the $26.00 per unit Pioneer tech fee plus another $24.00 in added premium. The retail price premium was over $40.00 per unit for four matched pairs of Pioneer varieties, and under $15.00 in three cases. Clearly varietal performance and the interaction of supply and demand exert significant influence on the pricing of corn varieties offered by any single company.

A third method focused on price premiums for the leading *Bt* varieties sold by eight companies in three Doane maturity groups in crop year 2000. We identified the best-selling *Bt* variety offered by each company in these three maturity groups and compared the prices for this variety to the most comparable conventional variety in the same maturity group. In four cases there appeared to be no matching variety for sale in 2000, so Table 7 reports the results for 20 matched pairs of *Bt*-conventional varieties. On average, the retail price premium was $25.75 and the net price premium was $26.57.

Table 6. Retail and Net Prices per Unit, Discounts and Price Premiums for 19 Pairs of Pioneer Hi-Bred International *Bt* Hybrids Matched to their Base Genetics, 1998-2000 [Ranked

Year	Matched Pair	Doane Maturity Group	*Bt* Variety			Base Genetics			Price Premiums	
			Average Retail Price	Average Discount	Average Net Price	Average Retail Price	Average Discount	Average Net Price	Average Retail	Average Net
1999	1	5	$ 164.88	$ 12.52	$ 152.36	$ 108.42	$ 6.71	$ 101.71	$ 56.46	$ 50.65
2000	2	5	$ 114.93	$ 10.91	$ 104.02	$ 63.13	$ 8.49	$ 54.64	$ 51.80	$ 49.38
1999	3	6	$ 152.19	$ 8.97	$ 143.22	$ 105.27	$ 7.11	$ 98.16	$ 46.92	$ 45.06
1999	4	10	$ 128.00	$ 20.00	$ 108.00	$ 87.05	$ 7.07	$ 79.98	$ 40.95	$ 28.02
1999	5	2	$ 121.14	$ 9.30	$ 111.84	$ 84.10	$ 4.09	$ 80.01	$ 37.04	$ 31.83
1998	6	5	$ 129.39	$ 9.46	$ 119.93	$ 93.11	$ 6.66	$ 86.45	$ 36.28	$ 33.48
1999	7	6	$ 123.68	$ 15.98	$ 107.70	$ 88.99	$ 10.00	$ 78.99	$ 34.69	$ 28.71
1999	8	7	$ 138.88	$ 22.97	$ 115.91	$ 107.78	$ 8.99	$ 98.79	$ 31.10	$ 17.12
1998	9	4	$ 117.71	$ 9.63	$ 108.08	$ 88.27	$ 5.54	$ 82.73	$ 29.44	$ 25.35
2000	10	3	$ 115.79	$ 9.03	$ 106.76	$ 86.37	$ 6.00	$ 80.37	$ 29.42	$ 26.39
1999	11	4	$ 135.92	$ 11.71	$ 124.21	$ 107.20	$ 14.46	$ 92.74	$ 28.72	$ 31.47
1999	12	3	$ 116.81	$ 8.53	$ 108.28	$ 88.18	$ 6.78	$ 81.40	$ 28.63	$ 26.88
1999	13	5	$ 121.49	$ 12.00	$ 109.49	$ 94.67	$ 8.76	$ 85.91	$ 26.82	$ 23.58
1999	14	9	$ 133.92	$ 15.00	$ 118.92	$ 108.92	$ 8.12	$ 100.80	$ 25.00	$ 18.12
2000	15	10	$ 121.96	$ 8.13	$ 113.83	$ 97.32	$ 8.56	$ 88.76	$ 24.64	$ 25.07
2000	16	4	$ 116.52	$ 9.34	$ 107.18	$ 94.37	$ 6.31	$ 88.06	$ 22.15	$ 19.12
1999	17	4	$ 107.07	$ 9.62	$ 97.45	$ 92.31	$ 5.66	$ 86.65	$ 14.76	$ 10.80
2000	18	11	$ 109.17	$ 18.42	$ 90.75	$ 96.61	$ 10.02	$ 86.59	$ 12.56	$ 4.16
2000	19	2	$ 117.32	$ 9.33	$ 107.99	$ 108.42	$ 16.91	$ 91.51	$ 8.90	$ 16.48
Average Matched Pairs			$ 141.10	$ 10.93	$ 130.18	$ 108.42	$ 11.81	$ 96.61	**$ 32.68**	**$ 33.57**

Source: Benbrook Consulting Services, based on Doane Marketing Research Inc. corn seed surveys, 1998-2000

Again, there is a wide range in price premiums, with four cases over $30.00 per unit of seed and three under $10.00 per unit.

Comparing the prices of *Bt* varieties with closely matched cousins provides useful insights but can also be misleading as an indicator of the *Bt* corn price premium. Nor is it a direct measure of the technology's value from the perspective of farmers. For the price premium to be a reflection of farmers' perceptions of value, the difference in prices would have to be solely attributed to the added presence of the *Bt* trait. This, in turn, assumes that companies invest roughly equal effort in marketing the *Bt* and conventional versions of the same hybrid and that supplies sufficient to meet demand are equally available of both the *Bt* variety and its base genetics. Both these assumptions are likely not valid in many cases.

Three methods of calculating the average price premiums paid by farmers for *Bt* corn seed produce similar average results. In the balance of this analysis, we conclude that the average price premium paid for *Bt* corn was $30.00 per unit in 1996 through 1998, and $26.00 per unit in 1999-2001.

Table 7. Price Premiums Paid for Leading *Bt* Varieties Compared to Base Genetics Sold by Eight Companies in Three Maturity Groups, 2000					
Company	**Doane Maturity Group**	**Matched Pair**	**Market Share of *Bt* Variety by Company and Maturity Group**	**Premium Based on Retail Prices**	**Premium Based on Net Prices**
CARGILL HYBRID SEEDS	5	1	82%	$ 40.04	$ 41.68
DEKALB PLANT GENETICS	5	2	19%	$ 23.00	$ 19.93
GOLDEN HARVEST SEED CO.	5	3	26%	$ 24.69	$ 26.32
MYCOGEN SEEDS	5	4	24%	$ 4.06	$ 1.76
NOVARTIS SEEDS	5	5	44%	$ 13.37	$ 10.00
PIONEER HI-BRED INTERNATIONAL	5	6	16%	$ 20.83	$ 17.92
STINE SEED COMPANY	5	7	49%	$ 5.15	$ 6.65
CARGILL HYBRID SEEDS	6	1	29%	$ 25.00	$ 25.64
DEKALB PLANT GENETICS	6	2	29%	$ 16.30	$ 15.68
GARST SEEDS	6	3	79%	$ 7.91	$ 4.24
GOLDEN HARVEST SEED CO.	6	4	20%	$ 35.95	$ 31.75
MYCOGEN SEEDS	6	5	30%	$ 21.99	$ 23.74
NOVARTIS SEEDS	6	6	42%	$ 25.81	$ 28.24
PIONEER HI-BRED INTERNATIONAL	6	7	30%	$ 29.46	$ 26.85
DEKALB PLANT GENETICS	7	1	23%	$ 39.79	$ 37.71
GOLDEN HARVEST SEED CO.	7	2	56%	$ 19.05	$ 17.51
MYCOGEN SEEDS	7	3	23%	$ 23.28	$ 20.38
NOVARTIS SEEDS	7	4	36%	$ 12.80	$ 8.61
PIONEER HI-BRED INTERNATIONAL	7	5	42%	$ 30.12	$ 23.85
STINE SEED COMPANY	7	6	100%	$ 11.46	$ 11.46
Average 20 Matched Pairs				**$ 25.75**	**$ 26.57**
Source: Benbrook Consulting Services, based on Doane Marketing Research, Inc. corn survey results for 1998-2000.					

Variability in the price premium is surprisingly large. In some cases the price premium is almost double, in other cases less than one-half of the standard, reported technology fee of $24.00 to $30.00 per unit. This finding probably reflects the fact that the supplies of *Bt* varieties and their closely matched conventional cousins did not always match farmer-demand, leading seed companies and retailers to either reduce or increase base prices and/or discounts, in some cases markedly.

2. Do High-Priced Hybrids Deliver Higher Yields?

Several factors no doubt contribute to the surprisingly large range in the price of corn seed. The seed supply for each year is grown the year before, requiring companies to project demand a year in advance. Many factors can shift the acres planted to corn in a given region or nationally. Such shifts clearly affect supply-demand interactions in the pricing of corn seed in different maturity groups.

The relatively high price paid for some *Bt* varieties likely reflects the fact that quantities were limited relative to demand. The strong demand was, in turn, created to some degree by the prominent advertising and marketing efforts accompanying the release of new *Bt* varieties. Likewise, the low net price paid for some varieties reflects a relative oversupply of seed and the need for dealers to offer larger discounts and other sales incentives to clear inventories.

While supply-demand imbalances are important variables influencing price, performance remains key. Each year corn producers pay close attention to the thousands of comparative yield trials carried out by universities, private companies, and seed manufacturers. Higher-priced hybrids that earn and hold marketshare are typically at or near the top in yields relative to other hybrids suitable for the same area and farming system. When and as a new variety proves itself and offers farmers a chance to reduce seed costs while maintaining their yields, farmers are rarely hesitant to switch.

The difference between high priced *Bt* corn varieties in a given maturity group and moderate priced conventional varieties is often over $50.00 per unit, or $17.50 per acre (based on an average of 2.86 acres planted per unit). At $1.75 net return per bushel, a farmer would need to harvest 10 or more bushels per acre to cover the added cost of seed. A net return of $1.75 is realistic with corn selling for about $2.00 per bushel since some variable costs are driven solely or largely by yields (fertilizer, drying, harvest and handling, storage). In comparing the net returns per acre in this section, we use $1.75 as the value to the farmer of a one bushel change in corn yields.

Several sources of data on comparative yields were used to explore the relationship between corn hybrid prices and yields. Each year *Farm Journal* magazine runs a story comparing the performance of many top corn hybrids. The corn seed article in early 2001 reports yield trial results from crop season 2000. Yield trials were conducted by independent contract research firms and carried out in Danville, Illinois, Council Bluffs, Iowa and Oxford, Indiana (see Appendix 1 for more detail on the *Farm Journal* trials). The results are reported in Table 8.

The yield information in Table 8 is from the 2001 corn seed *Farm Journal* article; the seed price data are from Doane Marketing Research, Inc. Company and variety numbers are not included in the table to avoid disclosing Doane price information for a specific variety.

In Danville Illinois trials, the top yielding variety cost growers $98.00 per unit, about in the middle of the price range ($86.36 per unit to $116.73). It out-produced another variety sold for the same price per unit by a remarkable 33.6 bushels.

The four top yielding varieties produced over 190 bushels per acre and sold for $98.00 to $92.02 per unit. They produced at least 20 bushels more than the high-cost, herbicide tolerant variety that sold for $116.73 per unit. Farmers planting the high-yield conventional variety spent $0.17 on seed per bushel harvested; growers planting the high-cost herbicide tolerant variety spent $0.23 on seed per bushel harvested. The top variety produced about $43.75 more net revenue than the high-cost, herbicide tolerant (HT) variety and cost about $6.55 less per acre, for a profit advantage per acre over $50.00. Since corn herbicide costs per acre are on the order $20.00 to $30.00, it is not possible that lower weed management costs made up for the loss in income.

Table 8. Price and Yields of Selected Varieties in Three Locations Ranked by Yield, *Farm Journal* Coverage of Corn Varietal Trials, 2000

Company and Variety	Seed Type	2000 Retail Price	Yield (bu/acre)	Source
1	Conventional	$ 98.00	199	Danville, IL
2	Conventional	$ 94.84	198	Danville, IL
3	Conventional	$ 92.02	196	Danville, IL
4	Conventional	$ 92.22	194	Danville, IL
5	Conventional	$ 108.09	188	Danville, IL
6	Conventional	$ 104.69	184	Danville, IL
7	Conventional	$ 89.67	176	Danville, IL
8	Conventional	$ 86.36	176	Danville, IL
9	HT	$ 116.73	174	Danville, IL
10	Conventional	$ 108.66	172	Danville, IL
11	Conventional	$ 98.00	165	Danville, IL
12	Conventional	$ 91.20	163	Danville, IL
1	Stacked	$ 101.80	171	Council Bluffs, IA
2	Conventional	$ 70.05	168	Council Bluffs, IA
3	Conventional	$ 88.99	165	Council Bluffs, IA
4	Conventional	$ 99.51	164	Council Bluffs, IA
5	*Bt*	$ 132.28	161	Council Bluffs, IA
6	*Bt*	$ 118.01	161	Council Bluffs, IA
7	*Bt*	$ 123.38	160	Council Bluffs, IA
8	*Bt*	$ 116.44	159	Council Bluffs, IA
9	*Bt*	$ 112.44	157	Council Bluffs, IA
10	*Bt*	$ 108.08	156	Council Bluffs, IA
11	Conventional	$ 100.00	156	Council Bluffs, IA
12	*Bt*	$ 132.58	155	Council Bluffs, IA
13	Conventional	$ 99.51	154	Council Bluffs, IA
14	Conventional	$ 88.76	154	Council Bluffs, IA
15	*Bt*	$ 102.41	153	Council Bluffs, IA
16	Stacked	$ 91.55	154	Council Bluffs, IA
17	*Bt*	$ 97.16	152	Council Bluffs, IA
1	Conventional	$ 84.29	167	Oxford, IN
2	*Bt*	$ 111.46	162	Oxford, IN
3	Conventional	$ 95.12	164	Oxford, IN
4	*Bt*	$ 104.93	161	Oxford, IN
5	Conventional	$ 99.01	162	Oxford, IN
6	*Bt*	$ 134.00	155	Oxford, IN
7	Conventional	$ 95.65	153	Oxford, IN
8	Conventional	$ 78.24	149	Oxford, IN
9	*Bt*	$ 113.40	147	Oxford, IN
10	*Bt*	$ 101.53	149	Oxford, IN
11	HT	$ 60.00	145	Oxford, IN
12	Conventional	$ 81.41	138	Oxford, IN
13	Conventional	$ 104.94	140	Oxford, IN
14	Conventional	$ 83.99	139	Oxford, IN

Source: Benbrook Consulting Services. Varieties identified in "Right Seed for the Job," *Farm Journal*, Mid-January 2001. Prices from the Doane Marketing Research, Inc. corn seed survey.

The top yielding variety in Council Bluffs trials yielded 171 bushels and cost $101.80 per unit. It was a stacked variety with both the *Bt* gene and herbicide tolerance. The second best hybrid yielded three bushels fewer but cost $31.75 less per unit. The most expensive hybrid contained the *Bt* gene and yielded 154 bushels, about 17 bushels less than the top performing variety. The top yielding conventional variety produced 168 bushels and cost $70.05 per unit. High-cost *Bt* varieties were over $132.00 per unit -- $62 dollars more – and produced more than 10 bushels less, for a per acre profit difference of about $39.00.

In the Oxford Indiana trials, a conventional variety produced the top yield and cost $84.29 per unit, $15.00 to $50.00 less than the *Bt* varieties tested. A very low cost herbicide tolerant variety performed reasonably well, yielding 145 bushels, just 10 bushels less than a *Bt* variety costing $74.00 more per unit.

Table 9 reports similar comparative yield and price data from testing carried out in 2000 by the DeKalb County Test Plot Committee, with assistance from Purdue University Cooperative Extension. Nine varieties known to be well adapted to the area were including in the trials. Results reflect averages over multiple plots. Here the low-cost variety was also the top performer, producing 141 bushels per acre. The second-best hybrid contained the *Bt* gene and yielded 140 bushels, but cost almost $18.90 more per acre. The high-price variety also contained the *Bt* gene but was the poorest performer, yielding 129 bushels.

Table 9. DeKalb County Test Plot Committee Trial Results and Variety Prices Ranked by Yield, 2000

Company and Variety	Seed Type	2000 Retail Price	Yield (bu/acre)
1	Conventional	$ 72.00	141
2	*Bt*	$ 126.94	140
3	*Bt*	$ 104.93	139
4	*Bt*	$ 127.12	136
5	Conventional	$ 107.22	136
6	Conventional	$ 93.94	134
7	Conventional	$ 99.99	133
8	Conventional	$ 89.85	131
9	*Bt*	$ 128.04	129

Source: Benbrook Consulting Services, based on “2000 DeKalb County Corn Plot Results”, DeKalb County Test Plot Crops Committee and Purdue University Cooperative Extension Service.

Table 10. F.I.R.S.T. Performance Results amd Variety Prices for Central Iowa Ranked by Yield, 2000

Company and Variety	Seed Type	2000 Retail Price	Yield (bu/acre)
1	*Bt*	$ 101.95	184
2	*Bt*	$ 138.49	179
3	Stacked	$ 101.80	177
4	Conventional	$ 84.61	176
5	Conventional	$ 80.51	173
6	Conventional	$ 89.73	171
7	Conventional	$ 91.12	170
8	Conventional	$ 93.39	169
9	Conventional	$ 104.69	168
10	*Bt*	$ 101.01	168
11	Stacked	$ 91.55	167
12	*Bt*	$ 120.43	163
13	*Bt*	$ 118.00	163
14	*Bt*	$ 126.82	162
15	*Bt*	$ 108.08	161
16	*Bt*	$ 129.93	160
17	Conventional	$ 98.43	160
18	Conventional	$ 93.64	156
19	*Bt*	$ 124.58	156
20	Conventional	$ 88.99	156
21	Conventional	$ 92.00	156
22	*Bt*	$ 132.33	155
23	*Bt*	$ 132.58	154
24	*Bt*	$ 123.00	154
25	*Bt*	$ 116.81	153
26	*Bt*	$ 117.33	153
27	*Bt*	$ 121.53	153
28	*Bt*	$ 112.44	151
29	*Bt*	$ 121.53	151
30	*Bt*	$ 112.44	148
31	Conventional	$ 92.07	147
32	Conventional	$ 106.20	144

Source: Benbrook Consulting Services, based on "Year 2000 Better Hybrids Performance Summaries," Iowa Edition, Farmer's Independent Research of Seed Technologies (F.I.R.S.T.), Summary of the independent corn research trials conducted in Iowa.

Bt varieties performed well in a third set of trials. These were carried out in multiple Iowa locations by F.I.R.S.T., Farmer's Independent Research on Seed Technologies. F.I.R.S.T. carries out thousands of trials across the Corn Belt and is a trusted source of independent information on varietal performance. Annual reports are available for selected states and report data in several ways (ranked by yield, moisture, and economic return). Tables 10 and 11 report F.I.R.S.T. results for the central and northern parts of Iowa in 2000.

Table 11. F.I.R.S.T. Performance Results and Variety Prices for North Iowa Trials Ranked by Yield, 2000			
Company and Variety	Seed Type	2000 Retail Price	Yield (bu/acre)
1	Conventional	$ 90.67	170
2	*Bt*	$ 135.76	166
3	Conventional	$ 91.12	166
4	Conventional	$ 90.22	164
5	*Bt*	$ 101.01	164
6	Conventional	$ 96.14	164
7	Conventional	$ 102.20	164
8	HT	$ 90.58	162
9	Conventional	$ 87.00	162
10	*Bt*	$ 96.40	161
11	Conventional	$ 93.36	160
12	*Bt*	$ 128.28	159
13	Conventional	$ 84.66	159
14	*Bt*	$ 110.99	159
15	*Bt*	$ 100.81	158
16	*Bt*	$ 123.00	158
17	Conventional	$ 108.99	158
18	Conventional	$ 97.86	156
19	*Bt*	$ 126.94	155
20	Conventional	$ 88.02	155
21	Conventional	$ 94.24	155
22	Conventional	$ 99.01	154
23	*Bt*	$ 116.69	154
24	Conventional	$ 93.97	154
25	HT	$ 106.50	153
26	Conventional	$ 78.84	153
27	*Bt*	$ 132.90	153
28	*Bt*	$ 124.69	153
29	Conventional	$ 89.42	153
30	*Bt*	$ 127.12	147
31	*Bt*	$ 116.94	142
32	*Bt*	$ 100.99	137

Source: Benbrook Consulting Services, based on “Year 2000 Better Hybrids Performance Summaries,” Iowa Edition, Farmer’s Independent Research of Seed Technologies (F.I.R.S.T.), Summary of the independent corn research trials conducted in Iowa.

In Central Iowa tests, the top three varieties contained the *Bt* gene and yielded from 177 to 184 bushels. They also varied widely in price – from $101 to $138 per unit. One of the lower-cost *Bt* varieties was the top performer, although the most expensive variety tested came in second in terms of yield, at 179 bushels per acre. The best conventional variety produced 176 bushels, eight less than the top *Bt* variety, but cost $5.94 less per acre. The top conventional variety produced about $8.00 less income per acre than the top *Bt* variety, about the same income as the second-best *Bt* variety, and about $4.00 more profit per acre than the third-best *Bt* variety.

The top conventional hybrids were equally or more profitable for farmers than all but one of the *Bt* varieties tested. Two of the most expensive *Bt* varieties, selling for $132 per unit, yielded about 20 bushels less than the top conventional varieties. The difference in net returns per acre is again dramatic – on the order of $50.00 per acre.

In North Iowa F.I.R.S.T. testing, a conventional variety was the top performer and a relative bargain at $90.67 per unit of seed. The best *Bt* variety yielded four bushels less but cost $15.77 more per acre, for more than a $22.00 difference in farmer-profit. The difference in profit is even more dramatic when comparing the high-cost *Bt* variety to the top-performing conventional hybrid. The high-cost *Bt* variety came in 27th in yield at 153 bushels and cost $46.47 per acre, for a profit difference of about $44.00 per acre.

3. Total Direct Costs of *Bt* Corn Hybrids

The total premium paid by farmers planting *Bt* corn hybrids is equal to the total number of acres planted multiplied by the average price premium. Table 12 presents the results for 1996-2001.

Over the last six years, corn growers planting *Bt* varieties have paid $659.1 million more for their seed than growers planting otherwise similar conventional varieties. For some varieties, the magnitude of the price premium was substantially greater than the typical industry technology fee of $24.00 to $30.00 per unit of seed sold. But for many other varieties, the premium charged was less than the minimal tech fee. In the case of StarLink corn, no tech fee was charged.

Corn producers not planting *Bt* corn over this period spent on average about $28.00 per acre on seed. Farmers planting *Bt* varieties spent on average about $37.80, an increase of about 35 percent.

We now turn to the question of what farmers received for their added investment of $659 million in seed costs. The answer lies in two key variables – the reduction in yields expected per European Corn Borer found on corn plants and actual field insect population levels.

Table 12. Increased Expenditures for *Bt* Corn Hybrids at the National Level, 1996-2001							
	1996	**1997**	**1998**	**1999**	**2000**	**2001**	**1996-2001 Totals**
Acres Planted to *Bt* Varieties (1,000 acres)	1,109	6,045	13,788	16,174	16,943	15,222	69,281
Average *Bt* Corn Premium per Acre	$ 10.50	$ 10.50	$ 10.50	$ 9.10	$ 9.10	$ 9.10	
Increased Cost of *Bt* Corn Acres Planted (Million dollars)	$ 11.65	$ 63.47	$ 144.78	$ 147.18	$ 154.18	$ 138.52	$ 659.78
* Percent acres planted to *Bt* varieties from Table 3, includes stacked varieties with *Bt* and herbicide tolerant traits. The premium per acre does not include the technology fee associated with the herbicide tolerant trait in stacked varieties.							
Source: Benbrook Consulting Services, 2001.							

II. Impact of *Bt* Corn on Farmer Returns

The benefits of *Bt* corn come largely from increased yields, brought about by lessened damage from the European Corn Borer (ECB). Outside the heart of the Corn Belt, other Lepidopteran insects are the most important, especially the Southwestern Corn Borer (SWCB). Throughout this section, damage estimates are largely based on the ECB, but in states where the SWCB is common, yield losses attributed to the ECB are meant to encompass both feeding damage from the ECB and SWCB.

The toxins expressed in the tissues of *Bt* corn plants kill ECB, SWCB and some other Lepidopteran insects, reducing tunneling inside the corn plant and helping reduce the chance that pathogens will gain a foothold in a cornfield. (Injured corn plants are more susceptible to a variety of diseases and molds).

Tunneling reduces yields in two major ways – by reducing the flow of moisture and nutrients as the corn plant grows; and second, by increasing the number of plants that fall over prior to harvest, leading to difficulties during harvest (often referred to as "lodged" plants). In some cases, insect damage can also cause corn ears to fall off of plants. Once on the ground, the grain in the ears is lost during harvest operations. (In some regions, such corn is an important post-harvest feed source for cattle grazing in cornfields).

In the absence of ECB or other Lepidopteran insect pressure, *Bt* corn confers no advantage to the plant or farmer. The assessment of the benefits of *Bt* corn, then, rests upon two factors –

- Annual levels of ECB/SWCB in corn production fields, and
- The likely yield reduction caused by ECB/SWCB feeding damage.

A. European Corn Borer Injury Estimates and Economic Thresholds

Land grant university entomologists in every state growing significant quantities of corn have extensively studied the ECB and/or the SWCB for decades. Several states have compiled ECB population data since the 1940s and some continue to carry out extensive ECB population surveys (see next section for a review).

Likewise, all states have developed economic thresholds and relatively sophisticated models for farmers to use in deciding whether to treat a field infested with ECBs. When a farmer is deciding whether to spray an insecticide, the economic threshold is a function of the yield goal on the field, the potential reduction in yields caused by ECB feeding, the price of corn per bushel, the cost of treating an acre with a particular insecticide, and the likely effectiveness of the insecticide application in reducing ECB damage.

The physiological part of these models project the corn yield damage likely to be caused by a given number of ECBs per plant in a field. The most common measures of ECB pressure are the percent of plants infested and the average number of ECB larvae per stalk. Essentially the same physiological parameters are used in determining whether it makes economic sense to spray an insecticide or plant *Bt* corn in a given field.

Farmers wanting to estimate the potential yield gain from spraying their fields for the ECB/SWCB or planting *Bt* corn need to determine the number of ECBs/SWCBs in their production fields.

Historically, few farmers spray insecticides to manage the ECB because it is an episodic pest that usually does not reduce yields significantly and because it takes considerable skill and effort to apply insecticides effectively. Scouting ECB population levels is essential to properly time applications and costs as much as $4.00 per acre. Under the best of circumstances, entomologists project that insecticide spraying reduces ECB damage by 75 percent.

Planting *Bt* corn to manage the ECB/SWCB is more attractive to farmers than spraying insecticides for three reasons. First, *Bt* corn is close to 100 percent effective in avoiding yield loss from the ECB/SWCB. Second, it requires no scouting of fields or additional management focus and third, it eliminates the need to spray large volumes of typically high-risk insecticides.

If *Bt* corn seed sold for about the same price as other seed, adoption rates would be much higher. But as reported above, *Bt* corn seed is more expensive, leading to the question whether the added expenditure on *Bt* corn varieties has been a good investment by farmers. Once harvested, the marketing of *Bt* corn also imposes additional costs on the farm sector, and the flow of genes from *Bt* cornfields to conventional and organic production fields remains a major concern posing costs of unknown magnitude. Here the focus is solely on whether the investment in *Bt* corn pays off for the farmer in light of increased seed costs.

State ECB Damage Estimates and Treatment Thresholds

Years of data and much research across several states have produced comparable estimates of the damage done to corn yields per European Corn Borer infesting a plant. Most scouting and survey data is reported per 100 corn plants. When 32 plants out of 100 sampled are found to be infested with one ECB larvae per plant, the population level used in damage assessment models would be 0.32 larvae per plant. If 10 of these 32 infested plants had 2 larvae per plant and the others just one, there would be a total of 42 larvae in the 100 plants, or on average 0.42 per plant.

Table 13 presents a summary of ECB damage estimates by state for first and second generation ECB, expressed as a percent of yield lost in a field with an average of one larvae per plant (or 100 per 100 plants). For example, in Illinois fields with one larvae of first-generation ECB per plant, the University of Illinois model projects a 4.5 percent loss in yield; if three larvae were found on average, the projected yield loss would be 13.5 percent.

State-level estimates of first generation ECB yield impacts range from a low of 4.5 percent (Illinois) to a high of 5.9 percent (Missouri). For states lacking published estimates of ECB losses to first-generation ECB, we use as an estimate 5.5 percent, a level toward the high-end of the 11 estimates in Table 13 and chosen to lessen the chances of underestimating the benefits of *Bt* corn.

Table 13. Projected Average Yield Loss Caused by One First Generation or One Second Generation European Corn Borer Per Plant, by State and Economic Thresholds for Insecticide Applications

State	Percent Yield Loss First Generation	Percent Yield Loss Second Generation	Economic Threshold for Insecticide Application
Colorado	No data		NA
Illinois	4.5	3.5	50% infestation
Indiana	5.8	4	0.5 borer/plants (50% infestation at 1 borer/plant)
Iowa	5.5	2.5	Varies
Kansas	no data		50% infestation at 1 exposed larvae/plant
Kentucky	5	2.5	1 borer/stalk, 50% infestation
Michigan	5	3	1 borer/tunnel at 50% infestation
Minnesota	5.5	2.8	50% of plants infested; > 200 borers/100 plants
Missouri	5.9	4	50% of plants infested
Nebraska	5	5	1.32 larvae per plant
New York	No data		NA
Ohio	5		50% of plants infested
Pennsylvania	No data		NA
South Dakota	5	4	1 larvae/plant
Texas	No data		NA
Wisconsin	5	4	50% infestation

Source: Benbrook Consulting Services. See Appendix 1, Table 1. for sources and further notes on damage estimates and economic thresholds.

The range of estimates caused by second-generation ECB vary somewhat more widely than first generation loss estimates and vary from a low of 2.5 percent (Iowa, Kentucky) to a high of 5 percent (Nebraska). In states lacking data on second-generation ECB damage, we assume an average yield loss of 4 percent, again toward the high-end of the estimates for 10 states reported in Table 13.

Comparing corn yields across fields as a function of the variety planted is tricky. Statistically reliable results require multiple years of data across thousands of test sites because from the farmer's perspective, the critical information is not how well a hybrid does in one, ideal growing season, but how well it will do on average in a given field with multiple soil conditions, across multiple combinations of biotic (e.g., insect pressure and weed competition) and abiotic factors (e.g., weather, compaction and soil fertility problems).

Many factors can and do impact the actual losses experienced in a given field from ECBs/SWCBs, whether first or second-generation insects. In years with otherwise perfect growing conditions, plants can sustain a higher level of ECB/SWCB damage with minimal yield loss, whereas in years when plants are stressed by other factors, the yield loss from one ECB/SWCB per plant can be increased. For example, in a field with weakened stalks from ECB tunneling, unusually dry weather can further reduce yields, as can high winds following a heavy rain (exacerbates lodging). But such inclement weather conditions, or other adverse biotic factors, will nearly always also have an adverse impact on the yields in nearby conventional fields. This is why it is so important to compare corn hybrid performance from trials properly set up and conducted side-by-side in the same field, eliminating nearly all other factors than can cause corn yields to vary.

B. ECB Population Levels

Over the years thousands of person-years have been invested in collecting field data on ECB populations. Some states are able to track ECB population levels since the 1940s. Other states never bothered to collect much ECB data, or stopped collecting ECB data years ago. Still, there are enough data across the major corn producing states to compile a reasonably good approximation of ECB levels and damage since 1996, the first year *Bt* corn was widely planted.

Tables 14-16 present an overview of ECB survey data available from various states for 1998, 1999, and 2000. (See Appendix 1, Table 2 for more details and sources of information on ECB population levels). Detailed ECB population levels over many years are available for several states and are summarized below.

Illinois

University of Illinois entomologists have carried out ECB population surveys from the early 1940s. Figure 1 presents the results of the ECB fall survey for 1982 through 2000. Note the very low levels of ECBs in 1997 and 1998 and the relatively low levels in 1998 and 2000. Table 17 reports data from Illinois from 1987 through 1996 covering the percent of plants infested and the average number of larvae per plant.

Minnesota

Minnesota has perhaps the most extensive database on ECB population levels of any state covering the years 1994 through 2001. In addition, the state has been conducting surveys since the early 1960s. Levels have exceeded one borer per plant in about 10 years since 1963. Very high populations occurred in 1995 when levels reached, on average, 3.5 ECBs per plant.

Table 14. European Corn Borer (ECB) Population Surveys by State, 1998 [see notes]

State	First Generation (borers/100 plants)	Percent Plants Infested	Second Generation (borers/100 plants)	Percent Plants Infested	Overwintering Larval Density (borers/100 plants)	Percent Plants Infested
Colorado	No data					
Illinois	(Subeconomic levels)	Black light trap catch data only	Black light trap catch data only		Fall survey discontinued for 1997 and 1998	
Indiana	0.3	1.5	No survey	Black light trap catch data only	0.11	NA
Iowa	No survey		No survey		No survey	
Kansas	Light and pheromone trap data only		Light trap data		No survey	
Kentucky	Moth flight and degree day reports		IPM insect trap counts done weekly by Patty Lucas, UK research center		Southwestern corn borer more of a problem in corn	
Michigan	Pheromone trap catches					
Minnesota	No field reports				20.5	24.4
Missouri	Pheromone moth trap reports only					
Nebraska	Black light trap counts only		Black light trap counts only		Black light trap counts only	
New York	No data					
Ohio	Light & pheromone trap data	Field observation; no larvae counts				
Pennsylvania	No data					
South Dakota	No data					
Texas	Pheromone trap catches					
Wisconsin	No data				5	NA

Note: Sampling date for first generation ECB typically are in June; mid-summer for second generation, and September/October for fall surveys.
Source: See Appendix 1, Table 1. for sources of information on ECB levels in selected states.

Table 15. European Corn Borer (ECB) Population Surveys by State, 1999 [see notes]

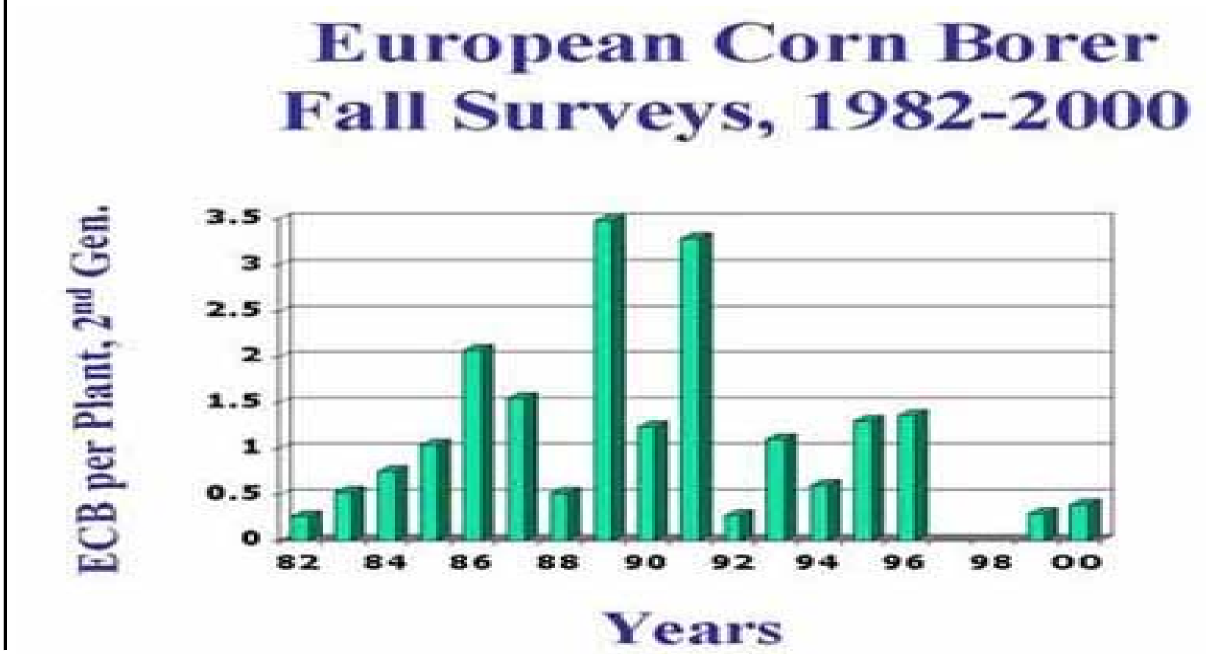
State	First Generation (borers/100 plants)	Percent Plants Infested	Second Generation (borers/100 plants)	Percent Plants Infested	Overwintering Larval Density (borers/100 plants)	Percent Plants Infested
Colorado	No data					
Illinois	No survey	Scouting reports only	No survey	Scouting reports only	29.4	24.3
Indiana	1.4	11.56	No survey	Black light trap catch data only	0.41	NA
Iowa	No survey		No survey		No survey	
Kansas	Light trap data		Light trap data		No survey	
Kentucky	Moth flight and degree day reports		IPM insect trap counts done weekly by Patty Lucas, UK research center		Southwestern corn borer more of a problem in corn	
Michigan	Pheromone trap catches					
Minnesota	5.5	5.4	12.8	10.1	26.6	22.8
Missouri	Pheromone moth trap reports only					
Nebraska	Black light trap counts only					
New York	No data					
Ohio	Light & pheromone trap data	Field observation; no larvae counts	Light & pheromone trap data		Bt variety trials for ECB evaluation; no county surveys for general ECB infestations	
Pennsylvania	No data					
South Dakota	Moth flight trap data only	Number of moths per trap/night from May to September				
Texas	Pheromone trap catches					
Wisconsin	No data		No data		30	NA

Note: Sampling date for first generation ECB typically are in June; mid-summer for second generation, and September/October for fall surveys.
See Appendix 1, Table 1. for sources of information on ECB levels in selected states.

Table 16. European Corn Borer (ECB) Population Surveys by State, 2000 [see notes]						
State	**First Generation (borers/100 plants)**	**Percent Plants Infested**	**Second Generation (borers/100 plants)**	**Percent Plants Infested**	**Overwintering Larval Density (borers/100 plants)**	**Percent Plants Infested**
Colorado	No data					
Illinois	No survey; scattered moth flight reports & heat unit accumulations		No survey		0.38	41.8
Indiana	1.8	36	No survey	Black light trap catch data only	0.38	NA
Iowa	No survey		No survey		No survey	
Kansas	Light and pheromone trap data only					
Kentucky	Moth flight and degree day reports		IPM insect trap counts done weekly by Patty Lucas, UK research center		Southwestern corn borer more of a problem in corn	
Michigan	ECB pheromone trap catches					
Minnesota	No field reports		No field reports		14.2	24.3
Missouri	Pheromone moth trap reports only					
Nebraska	Black light trap counts only					
New York	No data					
Ohio	Light & pheromone trap data		Light & pheromone trap data		Bt variety trials for ECB evaluation; no county surveys for general ECB infestations	
Pennsylvania	No data					
South Dakota	Moth flight trap data only					
Texas	Pheromone traps to monitor moth flights					
Wisconsin	No data		No data		24	NA

Note: Sampling date for first generation ECB typically are in June; mid-summer for second generation, and September/October for fall surveys.
Source: See Appendix 1, Table 1. for sources of information on ECB levels in selected states.

Figure 1. Illinois Statewide Averages for Second Generation European Corn Borers



Source: U. of Illinois "Pest Management & Crop Development" bulletin, March 16, 2001.
URL: http://www.ag.uiuc.edu/cespubs/pest/articles/200101g.html

Table 17. Illinois Fall European Corn Borer Larvae Survey Results, 1987-1996

Year	Percent Plants Infested	Average Number Larvae per Stalk
1987	78	1.55
1988	31	0.52
1989	78	3.48
1990	60	1.24
1991	91	3.30
1992	31	0.30
1993	50	1.10
1994	49	0.60
1995	65	1.30
1996	64	1.36

Source: "Corn Borer Densities, 1987 to 1996," Cooperative Extension Service, Univ. of Illlinois, 1997.

Mark Abrahamson, the Plant Pest Survey Coordinator in the Minnesota Department of Agriculture, provided detailed results of Minnesota surveys from 1994-

2001. Each year, fall (second generation) ECB larvae are counted in well over 300 locations statewide. The results are recorded by longitude and latitude to facilitate mapping and research on the efficacy of ECB management systems and technology.

In 1998 Minnesota ECB levels ranged from a low of zero to a high of 186 larvae per 100 plants. The average was 14.2 per 100 plants, or .142 per plant. About 55 percent of the 378 locations had less than 0.1 ECB per plant and only 10 of 378 locations had plants with greater than one ECB per plant. Table 18 reports these findings and similar data for 1999 and 2000.

Table 18. Minnesota Fall European Corn Borer Surveys (1998-2000) Data Summary

Year	Number of Locations	Number of Locations					
		Percent Plants Infested >50%	Percent Plants Infested <20%	Percent Plants Infested <10%	ECBs per Plant >1	ECBs per Plant > 0.5	ECBs per Plant <0.1
2000	344	48 [14%]	178 [52%]	108 [31%]	5 [1.5%]	12 [3.5%]	226 [66%]
1999	367	46 [12.5%]	218 [59.4%]	111 [30.2%]	17 [4.6%]	17 [4.06%]	177 [48%]
1998	378	51 [13.5%]	216 [57%]	86 [22.8%]	10 [2.6%]	12 [3%]	208 [55%]

Soure: Benbrook Consulting Services, see Appendix 2, Table 2 for further detail on data sources.

The 367 locations surveyed in 1999 produced similar results to 1998. The average population level per 100 plants was 26.2 in 1999, with 48 percent of the locations recording less than 0.1 ECD per plant. In 2000, populations were lower and averaged 14.2 per 100 plants.

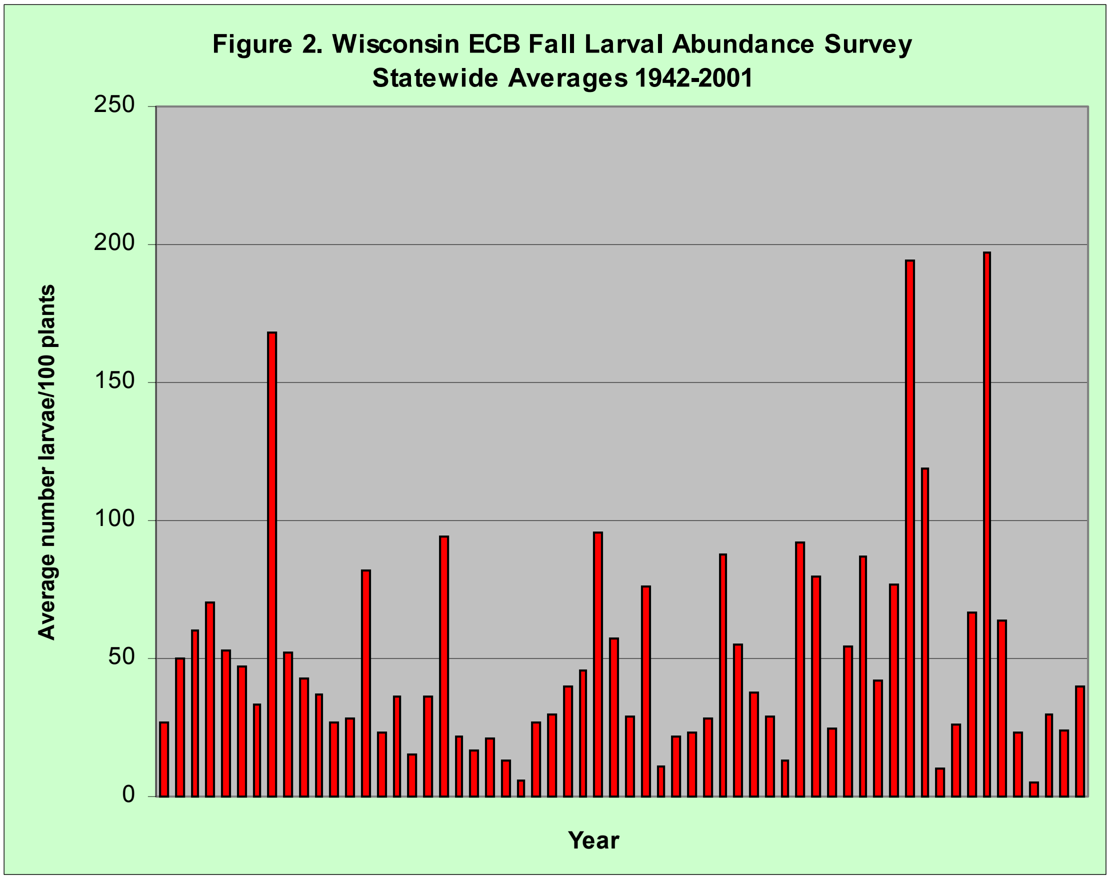
Wisconsin

Wisconsin can provide ECB population data back to 1942. Over the last 50 years ECB levels in fall surveys have exceeded 1 borer per plant in only four years, as shown in Figure 2.

Table 19 reports Wisconsin ECB data since 1992. ECB levels have exceeded one borer per plant in only one year out of the last 10. In five of the last 10 years, there have been 0.25 borers per plant or less in Wisconsin, and the average level has been under 0.5 ECB per plant. The data for 2001 for Wisconsin shows a significant jump in populations from 2000 to 2001, as does data covering several other states. (This is why the projected benefits to *Bt* corn are greatest in 2001).

1. Projecting Yield Losses from ECB Damage

Most published national estimates of the yield impact of *Bt* corn have been based largely on assumptions that were, in turn, based on a limited number of field trials. The EPA's *Bt* corn benefits assessment assumed that all *Bt* corn was grown under "low" or



"high" pest pressure, with the corn yield loss under "low" pressure averaging 5.4 percent of yields and average yield reductions of 10.81 percent in the high pressure scenario.

The "low" pressure scenario reflects an implicit EPA assumption that on average, there were about one first-generation ECB larvae per plant and/or about 1.5 second-generation ECB per plant in 1996-2001. The "high" pressure scenario reflects ECB population levels about twice as high – about 2 first generation and 3 second-generation larvae per plant. These assumptions markedly overstate ECB populations and yield damage, as evident from even a cursory review of state-by-state data on ECB populations. Average losses on the order of 5 percent to 10 percent may have occurred in a few years in a couple of states since the 1960s, but these are grossly inflated estimates of average annual losses, even in the states experiencing the greatest ECB pressure.

For each state producing significant acreage of corn in 1996-2001, an estimate of the benefits of *Bt* corn can be made using actual damage equations and ECB survey data. Average expected yield losses from both first and second-generation ECBs are used in making the estimates. Table 20 reports by state the expected yield loss per borer per plant for first and second-generation ECB/SWCB. The estimates are reasonably consistent across states. In a given field in a given year, losses from one ECB/SWCB per plant may be somewhat lower or higher. But on average, the losses predicted in Table 20 are generally regarded as representative of "routine" conditions.

Table 19. Wisconsin European Corn Borer Fall Survey Results 1992 - 2001 (Bold numbers in cells indicate larvae exceeds economic threshold)											
District	Average Number of Larvae per 100 Plants										
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Ten Year Average
Northwest	8	26	20	10	32	3	2	15	26	33	18
Northcentral	1	15	8	17	41	26	1	3	4	5	12
Northeast	37	2	10	53	47	18	1	18	3	7	20
Westcentral	10	17	45	121	80	15	2	30	31	67	42
Central	9	29	92	123	102	9	2	30	41	48	49
Eastcentral	9	13	28	**249**	65	26	3	25	19	33	47
Southwest	5	65	110	**631**	51	39	17	57	39	87	110
Southcentral	13	14	101	**265**	83	35	10	61	33	48	66
Southeast	5	40	107	**308**	79	35	10	31	16	36	67
State Average	11	25	58	**197**	64	23	5	30	24	40	48
Source: Wisconsin Department of Agriculture, Trade, & Consumer Protection Fall Abundance Survey; Melody Walker, State Entomologist. Data provided by Krista Lambrecht, survey entomologist.											

Some states have not developed ECB/SWCB damage models that can be used to project the corn yield reduction caused by one ECB/SWCB per plant. In such cases, an average of the damage estimates per ECB/SWCB per generation reported in nearby states was used and is incorporated in Table 20.

2. ECB Population Levels

Only a few states report both first and second-generation ECB population levels. In states reporting second-generation ECB levels only, we used data in other states on the relationship between first and second-generation population levels to approximate first generation levels. For example, Indiana reports data on both first and second-generation ECBs in 1998, 1999, and 2000 (see Tables 14-16). The relationship between spring and fall ECB levels is reasonably consistent in this state; the higher the first-generation population level, the bigger the difference between first and second-generation populations.

In 1998 in Indiana there were 0.3 first-generation ECBs per plant and 0.11 second-generation larvae. Accordingly, there were about 3 first-generation ECBs for each second-generation ECB. In 1999, there were 1.4 first-generation larvae and on average, 3.4 first generation larvae for each second-generation ECB found. In 2000, the year with the highest first-generation ECB population (1.8 ECB/plant), there were 4.7 first-generation larvae for each second-generation ECB. In Eastern Corn Belt states, our damage estimates reflect this Indiana data.

Table 20. Estimated ECB Percent Yield Damage by State on Acres of Corn Planted to Conventional Hybrids and Infested with One ECB per Plant, 1996-2001

State	First Generation ECB Damage per Borer per Plant	Second Generation ECB Damage per Borer per Plant
Colorado	5%	4%
Illinois	4.5%	3.5%
Indiana	5.8%	4%
Iowa	5.5%	3%
Kansas	5%	3%
Kentucky	5%	2.5%
Michigan	5%	3%
Minnesota	5.5%	2.8%
Missouri	5.9%	4%
Nebraska	5%	5%
New York	5%	4%
Ohio	5%	4%
Pennsylvania	5%	4%
South Dakota	5%	4%
Texas	5%	4%
Wisconsin	5%	4%
Other states	5%	4%

Source: Benbrook Consulting Services, 2001.

Minnesota is the only western Corn Belt state reporting both first and second-generation ECBs and these data are available for just 1999. In the Western Corn Belt, higher populations of second-generation ECBs are more common than in eastern states, so it is not surprising that there were 5.5 first-generation larvae per 100 plants and 12.8 second-generation ECBs, or 0.4 first generation ECB for each second-generation larvae.

Table 21 presents our estimates of first-generation ECBs per plant for 1996-2001 by state and Table 22 reports the same data for second-generation ECB larvae. The numbers in Tables 21-22 rely on hard data when available from state-level surveys (for an overview of available ECB survey data, see Tables 14-16 and Appendix 1, Table 2). For several states, anecdotal or geographically limited data were also used in making the estimates in Tables 21 and 22. With the exception of Wisconsin, Illinois, and Indiana, 2001 data must be viewed as preliminary. On the basis of the increase in levels in these three states between 2000 and 2001, population levels in other states were projected to also rise. This extrapolation may overstate actual populations and losses, and hence 2001 results must be viewed as preliminary.

Table 21. Estimated First Generation ECB Population Levels by State on Acres Corn Planted to Conventional Hybrids, 1996-2001						
State	**First Generation ECB Levels (Borers/plant)**					
	1996	**1997**	**1998**	**1999**	**2000**	**2001**
Colorado	1	1	1	1	1	1
Illinois	3	1	0.5	0.2	0.3	1.5
Indiana	1	0.5	0.3	1.4	0.6	0.8
Iowa	0.6	0.3	0.15	0.1	0.1	0.3
Kansas	0.5	0.3	0.1	0.1	0.1	0.3
Kentucky	1	0.6	0.2	0.6	0.3	0.5
Michigan	1	0.5	0.05	0.05	0.1	0.3
Minnesota	0.8	0.3	0.1	0.055	0.1	0.6
Missouri	2	0.7	0.35	0.35	0.35	1.5
Nebraska	1	0.5	0.1	0.1	0.2	0.4
New York	0.4	0.2	0.1	0.1	0.1	0.3
Ohio	1	0.5	0.2	0.8	0.3	0.9
Pennsylvania	0.3	0.2	0.1	0.1	0.1	0.3
South Dakota	1.5	0.5	0.2	0.2	0.3	0.9
Texas	1	1	1	1	1	1
Wisconsin	1	0.5	0.05	0.05	0.1	0.3
Other states	0.8	0.4	0.2	0.1	0.1	0.3
Source: Benbrook Consulting Services, 2001.						

Note the generally higher ECB population levels in the Southern and Western Corn Belt. These numbers reflect combined populations and damage triggered by the ECB and the SWCB. ECB and SWCB damage in this area is typically greater than to the north and east because of more than two generations of the ECB, coupled with multiple generations of the SWCB. Insect pressure in dry areas with long growing seasons also tends to be more consistent; hence the stable and relatively high estimates of insect levels and losses in Colorado and Texas.

Purdue researchers have developed a methodology designed to project the separate impacts of the ECB and SWCB in such states (Hyde et al., 2000). If replicated here, the method would add significant complexity to the analytical model and require data collection that is beyond the scope of the present study. In Tables 21 and 22, ECB levels and damage losses in Kansas, Texas, and Colorado have been increased roughly proportional to the combined ECB and SWCB losses reported in the Hyde study for Kansas. Further research is needed to refine loss estimates and models in regions with more than two generations of the ECB and/or populations of the SWCB.

3. Projecting ECB Losses Avoided on Acres Planted to *Bt* Corn

Several steps are required to calculate by state and year the number of bushels of corn likely to have been lost to ECB and/or SWCB pressure in the absence of *Bt* corn and other control measures.

Table 22. Estimated Second Generation or Overwintering ECB Population Levels by State on Acres Corn Planted to Conventional Hybrids, 1996-2001						
State	**Second Generation ECB Levels (Borers/plant)**					
	1996	**1997**	**1998**	**1999**	**2000**	**2001**
Colorado	2	2	2	2	2	2
Illinois	**1.36**	0.2	0.05	**0.29**	**0.34**	0.91
Indiana	0.7	0.4	**0.11**	**0.41**	**0.38**	0.5
Iowa	0.6	0.2	0.05	0.05	0.1	0.4
Kansas	0.6	0.3	0.2	0.1	0.1	0.3
Kentucky	0.6	0.3	0.1	0.1	0.1	0.3
Michigan	0.1	0.1	0.05	0.1	0.1	0.2
Minnesota	0.6	0.3	**0.205**	**0.128**	**0.142**	0.25
Missouri	0.6	0.2	0.1	0.1	0.1	0.4
Nebraska	0.6	0.4	0.1	0.1	0.2	0.4
New York	0.1	0.1	0.05	0.1	0.1	0.2
Ohio	0.5	0.3	0.05	0.1	0.1	0.2
Pennsylvania	0.1	0.1	0.05	0.1	0.1	0.2
South Dakota	0.4	0.1	0.05	0.1	0.1	0.2
Texas	2	2	2	2	2	2
Wisconsin	**0.64**	**0.23**	**0.05**	**0.3**	**0.24**	**0.4**
Other states	0.4	0.1	0.1	0.1	0.1	0.2
Source: Benbrook Consulting Services, 2001.						

First, the acreage planted to *Bt* corn must be approximated by state, drawing on USDA, EPA, and other data. **Appendix 2, Table 1** reports USDA data on the total acres planted to *Bt* and herbicide-tolerant corn varieties corn by state for 2000 and 2001. **Appendix 2, Table 2** reports the total number of acres of corn planted by state from 1996 through 2001.

Appendix 2, Table 3 reports the percent of these corn acres planted to *Bt* corn. Hard data for 1999-2001 were available on the distribution of *Bt* acres across the states included in Tables 14-22. The 1999 data are from the results of the Agricultural Biotechnology Stewardship's survey of growers reported to EPA and the 2000-2001 data are from USDA. In estimating the percent of acres planted to *Bt* varieties by state in 1996-1998, we assumed that each state's share of national *Bt* acres planted in 1996-1998 was the same as in 1999. Accordingly, the estimate for 1998 for a given state is equal to its 1999 share multiplied by the ratio of total national *Bt* acres in 1998 relative to 1999.

The percent of acreage in "Other States" planted to *Bt* hybrids has been adjusted each year so that the sum of *Bt* acres nationwide equals the total acres planted to *Bt* varieties (including stacked varieties) as derived from USDA, EPA, and Doanes and as reported in Table 3.

Total corn acres planted by state and the percent of acres planted to *Bt* hybrids are used to calculate total *Bt* acres (**Appendix 2, Table 4**). **Appendix 2, Table 5** contains USDA data on average corn yields by state and year. Assuming state average yields, the total numbers of bushels that would have been produced on acres planted to *Bt* corn are then calculated by multiplying acres planted by average yields (**Appendix 2, Table 6**).

Appendix 2, Table 7 combines the first and second-generation ECB damage estimates (Table 20) with population levels (Tables 21 and 22). The approach is simple and modestly overestimates total ECB/SWCB yield loss, since the yield reduction attributed to second-generation insects is added to the yield reduction from first-generation insects. This step does not adjust second-generation losses for the impact of first-generation feeding on yields. This combined percentage reduction is then used to estimate the number of bushels that would have been lost to the ECB/SWCB in the absence of *Bt* corn.

A caveat deserves emphasis. The projections of ECB/SWCB impacts on yields across the states for 1996-2001 rest on several assumptions regarding how to extrapolate data from overwintering or second-generation ECB populations to first-generation levels, and vice versa, and from one state to another. The connection between ECB/SWCB population levels and yield loss is, moreover, far from automatic. A number of factors can and do intervene during the growing season, either strengthening the plant's ability to contend with ECB/SWCB feeding, or exacerbating the damage caused by ECBs/SWCBs. Some estimates of yield impacts in **Appendix 2, Table 7** are no doubt high, while others are low. While imperfect, this method takes advantage of the data that are accessible and is clearly preferred to just assuming that *Bt* corn yields were increased 4 percent or 8 or 10 percent, as the EPA and other analysts have done.

The last step entails multiplying the combined first and second generation ECB/SWCB loss by the bushels of corn that would have been produced on the acres planted to *Bt* corn if standard hybrids had instead been planted. The results are reported in Table 23 for 1996-2001 and the six-year period. The state-level data in the table are the increase in the bushels of corn harvested by farmers planting *Bt* corn in each state. The last three lines in the table –

- Convert the increase in bushels harvested as a result of *Bt* corn to dollars, using average national market prices for corn from USDA;
- The premium paid by farmers in each state for *Bt* corn seed (from Table 12); and
- The net farm-level profit (loss) from planting *Bt* corn.

Nationwide in the six years since commercial introduction, *Bt* corn has increased corn production by an estimated 276 million bushels, valued at $567 million dollars. Farmers have paid $659 million more for *Bt* corn seed, resulting in a net loss of $92 million.

In three of the six years since commercial introduction, the investment in *Bt* corn has not paid off for the nation's corn producers. The losses in 1998, a year with low ECB populations in most Corn Belt states, were the greatest, whereas profits in 2001 were the largest in the six years since the introduction of *Bt* corn.

Table 23. The Production and Economic Impacts of *Bt* Corn, 1996-2001: Bushels of Corn Yield Loss Avoided, Value of Increased Yield, the *Bt* Corn Premium, and Impact on Farm-level Profits, 1996-2001

State	1996	1997	1998	1999	2000	2001	1996-2001 Totals
Colorado	369,200	2,246,149	5,477,784	6,811,740	6,240,780	6,027,840	27,173,493
Illinois	2,549,583	3,806,569	4,165,384	4,053,672	6,013,907	24,301,408	44,890,523
Indiana	276,438	820,573	995,390	5,230,579	3,016,440	5,056,819	15,396,240
Iowa	1,402,080	3,275,005	3,533,718	3,042,394	3,567,000	13,742,001	28,562,198
Kansas	283,227	888,071	1,035,368	923,832	932,880	3,881,196	7,944,574
Kentucky	139,707	355,056	306,811	900,900	484,120	1,146,880	3,333,474
Michigan	103,626	355,680	100,596	188,760	178,957	364,320	1,291,939
Minnesota	1,140,000	2,497,970	3,091,663	2,111,576	2,926,663	12,854,824	24,622,695
Missouri	739,555	1,218,781	1,344,871	1,393,982	317,950	1,468,800	6,483,940
Nebraska	1,685,493	4,974,442	2,723,418	3,108,040	5,569,200	14,710,800	32,771,393
New York	32,218	110,854	125,841	177,710	129,654	277,970	854,246
Ohio	93,240	409,106	295,849	1,147,608	614,739	2,275,416	4,835,958
Pennsylvania	13,114	46,178	59,319	56,700	97,441	133,950	406,701
South Dakota	897,867	1,416,606	1,719,979	2,107,224	3,385,648	8,873,304	18,400,628
Texas	611,520	3,895,545	7,683,624	9,810,450	9,478,560	6,697,600	38,177,299
Wisconsin	305,454	880,610	262,152	1,045,044	944,328	2,120,294	5,557,882
Other States	746,435	1,648,085	2,357,586	1,636,252	2,698,088	6,339,178	15,425,624
U.S. Total (Bushels)	11,388,756	28,845,280	35,279,353	43,746,462	46,596,356	110,272,601	276,128,808
Dollar Value Added Yield*	$ 30,863,529	$ 70,094,030	$ 68,441,944	$ 79,618,561	$ 86,203,258	$ 231,572,461	$ 566,793,785
Bt* Corn Price Premium	$ 11,690,000	$ 62,730,000	$ 144,720,000	$ 147,180,000	$ 154,250,000	$ 138,560,000	$ 659,130,000
Net Profit (Loss) from *Bt* Corn	$ 19,173,529	$ 7,364,030	$ (76,278,056)	$ (67,561,439)	$ (68,046,742)	$ 93,012,461	$ (92,336,215)

* Average market prices per bushel of corn by year are reported in Table 3. The "*Bt* Corn Price Premium" is from Table 8.

"*Bt* Corn Price Premium" based on the acres planted to *Bt* corn multiplied by the average technology fee in Table 12. Numbers differ slightly from Table 12 because of rounding in Table 12.

Source: Benbrook Consulting Services, 2001.

Note in 1998 that two states growing only 6.3 percent of the nation's *Bt* corn – Colorado and Texas – account for 45 percent of the bushels saved from planting *Bt* corn. This concentration of benefits along the southern and western edges of the Corn Belt reflects the relatively more stable and higher insect pressure in these states.

Another point must be stressed – the *Bt* corn price premium is not the only added cost that a farmer should take into account when deciding whether to plant *Bt* corn hybrids. The need to comply with refuge requirements adds a degree of management complexity during planting season, always a busy time. Depending upon where and how a farmer markets corn, they may be the need to segregate *Bt* corn from other grain and carry out tests on the conventional grain in storage on a farm, in order to satisfy a customer that the grain is not from a genetically engineered variety.

Bt corn is no different than all new technologies that increase production. The 276 million more bushels of corn on the market from 1996-2001 has had a ripple effect through the farm economy. The average price received by all farmers growing corn is marginally lower as a result.

International concern and controversy over *Bt* corn has also reduced export sales by hundreds of millions of bushels, increasing supplies in the U.S. and further decreasing prices from the levels they otherwise would have attained.

The planting of genetically engineered corn has emerged as a major issue of public concern. The stakes are high and broad, spanning environmental impacts, the prospect that resistance will render *Bt* useless, higher seed costs and narrower profit margins for farmers, loss of export markets, and gene flow and contamination of the nation's seed supply and corn germplasm.

It is hard to quantify the costs stemming from these indirect impacts of *Bt* corn and no one knows, nor can anyone predict with any level of certainty, whether these costs will increase or decrease over time. The answer depends in part on what scientists learn as they more carefully study the ecological and environmental impacts of *Bt*, and in part on how this technology is used.

Two factors lie behind much of the controversy surrounding *Bt* corn. Notwithstanding assurances to the contrary, there are important, possibly serious unresolved health, safety, and sustainability issues associated with the widespread planting of *Bt* corn. Second, this technology has proven very costly to develop, move through regulatory channels, commercialize, and market. Indeed, *Bt* corn imposes added costs on corn farmers and the food industry far in excess of benefits received. As a result, the financial performance and strength of certain biotechnology and seed companies has been improved at the expense of other sectors of the food industry, in particular farmers.

Appendix 1. Data Sources, Further Information and Literature Cited

EPA Information

Detailed EPA documents on the reregistration of *Bt* crops are accessible at the EPA Office of Pesticide Programs –
http://www.epa.gov/pesticides/biopesticides/reds/brad_bt_pip2.htm

Extensive information on the *Bt* crop reregistration process, including several comments submitted to EPA by scientists and public interest groups, is accessible at –

http://www.biotech-info.net/*Bt*_rereg.html

A detailed critique of the revised EPA *Bt* corn benefits assessment is available at – http://www.biotech-info.net/UCS_appendix3.pdf

EPA SAP Report No. 2000-07, "Sets of Scientific Issues Being Considered by the EPA Regarding: *Bt* Plant-Pesticides Risks and Benefit Assessments" is accessible at – http://www.epa/gov/scipoly/sap/2000/october/octoberfinal.pdf

USDA, National Agricultural Statistics Service reports used inlcude: *Acreage*, July 29, 2001; *Crop Production 2000 Annual Survey*, January 2001; *Agricultural Prices 2000 Annual Summary,* July 2001, and *Agricultural Prices 1998 Annual Summary*, July 1999. All are accessible at – http://www.usda.gov/nass/pubs/pubs.htm

Doane Marketing Research, Inc Corn Survey Data

1998-2000 U.S. Farm Corn Seed Survey, Doane Marketing Research, Inc., St. Louis, Missouri. Questionnaires are sent annually to approximately 4,500 commercial farms producing corn, providing the data used by Doane to produce estimates of the market share and prices of corn varieties. Participants are selected on the basis of geographical location and market representation. Seed, biotechnology and pesticide companies, in turn, utilize Doane survey data to assess the efficacy of their marketing strategies.

Trials Used to Compare Prices and Yields

Horstmeier, G., "Right Seed for the Job: Your 2001 Guide to Seed Selection," *Farm Journal*, Mid-January 2001. Results from Midwestern on-farm corn seed performance trials conducted by farm-management firms, Agri-Valley Farm Management, Council Bluffs, Iowa; Palmer Bank, Danville, Illinois; and FarmCraft Services, Oxford, Indiana.

"Year 2000 Better Hybrids Performance Summaries," Iowa Edition, Farmer's Independent Research of Seed Technologies (F.I.R.S.T.), Summary of the independent corn research trials conducted in Iowa.

"2000 DeKalb County Corn Plot Results", DeKalb County Test Plot Crops Committee and Purdue University Cooperative Extension Service.

Literature Cited

Benbrook, C., "Prevalence of Genetically Modified Traits in the Corn and Soybean Varieties Offered to Midwestern Farmers in Crop Year 2000," Ag Bio Tech Info Net Technical Paper Number 3, May 2000. http://www.biotech-info.net/technical_paper3.pdf

Carlson, G., Marra, M., and B. Hubbell, "Transgenic Technology for Crop Protection: The New 'Super Seeds'," *Choices*, Third Quarter, 1997.

Carpenter, J, and L. Gianessi, “Agricultural Biotechnology: Updated Benefit Estimates,” National Center for Food and Agricultural Policy report, January 2001. Accessible from http://www.ncfap.org/biotech.htm

“Genetically Engineered Crops: Has Adoption Reduced Pesticide Use?” USDA Economic Research Service, *Agricultural Outlook*, August 2000.

Farnham, D., and C. Pilcher, “*Bt* Corn Hybrid Evaluation: Year 2,” *Integrated Crop Management*, Iowa State University Extension publication, December 7, 1998.

Fernandez-Cornejo, J., and W. McBride, “Genetically Engineered Crops for Pest Management in U.S. Agriculture: Farm-Level Effects,” USDA, ERS, Agricultural Economic Report Number 786.

Gianessi, L., and J. Carpenter, “Agricultural Biotechnology: Insect Control Benefits,” National Center for Food and Agricultural Policy report, July 1999. Accessible from http://www.ncfap.org/biotech.htm

Hyde, J., Martin, M., Preckel, P., Edwards, R., and C. Dobbins, “Estimating the Value of *Bt* Corn: A Multi-State Comparison,” Selected Paper Presented at the American Agricultural Economics Association Annual Meeting, August 2000.

Hyde, J., Martin, M., Preckel, P., and R. Edwards, “The Economics of *Bt* Corn: Adoption Implications,” Purdue University Cooperative Extension publication ID-219, October 26, 2001.

Lauer, J. and J. Wedberg, “Grain Yield of Initial *Bt* Corn Hybrid Introductions to Farmers in the Northern Corn Belt,” J. of Production Agriculture, Vol. 12, No. 3, 1999.

Nielsen, R., “GMO Issues Facing Indiana Farmers in 2001,” Purdue University, Pest Management & Crop Production newsletter, March 23, 2001.

Olson, J., “When does *Bt* corn pay?” *Farm Industry News*, February 29, 2001.

Orr, D., and D. Landis, “Oviposition of European Corn Borer (Lepidoptera: Pyralidae) and the Impact of Natural Enemy Populations in Transgenic Versus Isogenic Corn,” J. of Economic Entomology, Vol. 90, 4:905-909, 1997.

Rice, M., “Yield Performance of *Bt* Corn,” *Integrated Crop Management*, Iowa State University Extension publication, January 1, 1998.

Steffey, K. and M. Gray. "Corn Borer Densities, 1987 to 1996," Cooperative Extension Service Pest Management Bulletin, December 5, 1997, Univ. of Illinois. http://www.ag.uiuc.edu/cespubs/pest/articles/v9725g.html

Wright, R., Hunt, T., Witkowski, J., Siegfried, B., and J. Foster, "Choosing a *Bt* Transgenic Corn Hybrid," *NebFacts*, University of Nebraska – Lincoln, Cooperative Extension Newsletter NF00-409.

"Yield Comparisons of *Bt* and Non-*Bt* Corn Hybrids in Missouri in 1999," U. of Missouri – Columbia, Integrated Pest & Crop Management Newsletter, Vol. 9., No.22, December 17, 1999.

Appendix 1, Table 1. Sources and Additional Comment on Damage Estimates and Economic Thresholds

State	Source
Colorado	no information
Illinois	University of Illinois Cooperative Extension newsletter No. 20/1998
Indiana	"The Economics of *Bt* Corn: Adoption Implications", Hyde, et al., Purdue University Extension publication
Iowa	"Effect of Planting Dates and *Bacillus thuringiensis* Corn on the Population Dynamics of European Corn Borer (Lepidoptera: Crambidae)", Pilcher, C.D. and M. E. Rice, J. of Economic Entomology, Vol. 94, No.3, June 2001.
Kansas	"Field Corn Insect Management 2001", Kansas State University Agricultural Experiment Station and Cooperative Extension Service publication . (Entomology 120)
Kentucky	"*Bt*-corn", University of Kentucky, College of Agriculture, Extension Entomology publication.
Michigan	"Corn Pre-harvest Loss from European Corn Borer 9-31-96", Michigan State University Extension, field crop CAT alerts 1996-2001, 09319605.
Minnesota	"*Bt* Corn & European Corn Borer" , Minnesota North Central Region Extension Publication NCR 602. Minnesota Department of Agriculture Plant Pest Survey bulletin.
Missouri	"European Corn Borer: A Multiple-Crop Pest in Missouri", University of Missouri – Columbia, Extension publication G7113, May 1, 2001.
Nebraska	"The European Corn Borer: Biology & Management", University of Nebraska Extension Entomology newsletter, July 11, 1997.
New York	no information
Ohio	"European Corn Borer", Ohio State University Extension, Ohio Pest Management & Survey Program, Field Crops Pest Management Circular #15.
Pennsylvania	no information
South Dakota	"Economic Thresholds of the European Corn Borer in South Dakota", South Dakota State University Cooperative Extension Service publication.
Texas	no information
Wisconsin	"Pest Management in Wisconsin Field Crops – 2001", University of Wisconsin Cooperative Extension publication - A3646.

Appendix Table 2. Sources of Information on ECB Population Levels and Surveys

State	Sources of Information and Comments
Colorado	no data
Illinois	University of Illinois Cooperative Extension Bulletins, "Pest Management & Crop Development", 11/3/2000, 11/5/1999
Indiana	Purdue University Cooperative Extension Service, "Pest & Crop" Newsletters No. 27 - 10/20/2000; No. 26 - 10/21/1999;
Iowa	Dr. Marlin Rice, Professor of Entomology, Iowa State University states that no surveys have been conducted in Iowa since the mid-1980's
Kansas	Kansas State University Research & Extension Newsletter
Kentucky	University of Kentucky, College of Agriculture, "Kentucky Pest News"
Michigan	Michigan State University Field Crop Advisory Team (CAT) Alert newsletters
Minnesota	MInnesota Department of Agriculture Plant Pest Surveys, Dr. Mark Abrahamson program coordinator
Missouri	University of Missouri, Integrated Pest & Crop Management Newsletter, Vol. 9, No.13, 1999
Nebraska	University of Nebraska, Institute for Agriculture & Natural Resources Cooperative Extension , "Crop Watch" newsletter
New York	no data
Ohio	Ohio State University Extension Entomology newsletter "C.O.R.N." (Crop Observation & Recommendation Network)
Pennsylvania	no data
South Dakota	South Dakota State University Extension Entomologist, Dr. Mark Catangui, will publish historical data in the Journal of Economic Entomology. Not publicly available until then.
Texas	Texas A & M University, Agricultural Extension Service
Wisconsin	Wisconsin Department of Agriculture, Trade, & Consumer Protection Fall Abundance Survey; Melody Walker, State Entomologist. Raw data provided by Krista Lambrecht, survey entomologist.

Appendix 2. Detailed Tables Used in Projecting Farm-Level Impacts of *Bt* Corn

Appendix 2, Table 1. USDA Estimates of the Percent of Corn Acres Planted to Genetically Engineered Varieties by State and U.S. Totals, 2000-2001

State	Percent Acres Insect Resistant (*Bt*) 2000	Percent Acres Insect Resistant (*Bt*) 2001	Percent Acres Herbicide Resistant 2000	Percent Acres Herbicide Resistant 2001
Illinois	13	12	3	3
Indiana	7	6	4	6
Iowa	23	25	5	6
Kansas	25	26	7	11
Michigan	8	8	4	7
Minnesota	28	25	7	7
Missouri	20	23	6	8
Nebraska	24	24	8	8
Ohio	6	7	3	4
South Dakota	35	30	11	14
Wisconsin	13	11	4	6
Other States 1/	10	11	6	8
U.S. Totals	**18**	**18**	**6**	**7**
State	**Percent Acres Stacked Gene Varieties 2000**	**Percent Acres Stacked Gene Varieties 2001**	**Percent Acres All Biotech Varieties 2000**	**Percent Acres All Biotech Varieties 2001**
Illinois	1	1	17	16
Indiana	*	*	11	12
Iowa	2	1	30	32
Kansas	1	1	33	38
Michigan	*	2	12	17
Minnesota	2	4	37	36
Missouri	2	1	28	32
Nebraska	2	2	34	34
Ohio	*	*	9	11
South Dakota	2	3	48	47
Wisconsin	1	1	18	18
Other States 1/	1	1	17	20
U.S. Totals	**1**	**1**	**25**	**26**

* Data rounds to less than 0.5 percent.

1/ "Other States" includes all other States producing corn not listed above.

Source: Acreage: Released June 29, 2001, by the National Agricultural Statistics Service (NASS), Agricultural Statistics Board, U.S. Department of Agriculture.

Appendix 2, Table 2. Total Acres Planted to Corn By State, 1996-2001						
State	**Area Planted 1996**	**Area Planted 1997**	**Area Planted 1998**	**Area Planted 1999**	**Area Planted 2000**	**Area Planted 2001**
Colorado	1,000,000	1,090,000	1,180,000	1,230,000	1,350,000	1,200,000
Illinois	11,000,000	11,200,000	10,600,000	10,800,000	11,200,000	10,900,000
Indiana	5,600,000	5,900,000	5,800,000	5,800,000	5,700,000	5,900,000
Iowa	12,700,000	12,200,000	12,500,000	12,100,000	12,300,000	11,900,000
Kansas	2,500,000	2,750,000	3,000,000	3,150,000	3,450,000	3,300,000
Kentucky	1,300,000	1,270,000	1,300,000	1,320,000	1,330,000	1,280,000
Michigan	2,600,000	2,500,000	2,300,000	2,200,000	2,200,000	2,200,000
Minnesota	7,500,000	7,000,000	7,300,000	7,100,000	7,100,000	6,900,000
Missouri	2,650,000	2,700,000	2,650,000	2,650,000	410,000	400,000
Nebraska	8,500,000	8,900,000	8,800,000	8,600,000	8,500,000	8,200,000
New York	1,150,000	1,170,000	1,130,000	1,150,000	980,000	1,100,000
Ohio	3,000,000	3,800,000	3,550,000	3,450,000	3,550,000	3,400,000
Pennsylvania	1,450,000	1,550,000	1,550,000	1,500,000	1,550,000	1,500,000
South Dakota	4,000,000	3,800,000	3,900,000	3,600,000	4,300,000	3,800,000
Texas	2,100,000	2,000,000	2,400,000	1,950,000	2,100,000	1,600,000
Wisconsin	3,900,000	3,850,000	3,700,000	3,600,000	3,500,000	3,400,000
Other States	8,279,000	7,857,000	8,505,000	7,186,000	10,025,000	9,129,000
U.S. Totals	79,229,000	79,537,000	80,165,000	77,386,000	79,545,000	76,109,000

Appendix 2, Table 3. Percent of Corn Acres Planted to *Bt* Corn

State	1996	1997	1998	1999	2000	2001
Colorado	2.0	10.9	24.6	30.0	28.0	28.0
Illinois	0.9	5.1	11.5	14.0	14.0	13.0
Indiana	0.5	2.5	5.7	7.0	7.2	7.2
Iowa	1.7	9.0	20.5	25.0	25.0	26.0
Kansas	1.7	9.4	21.3	26.0	26.0	27.0
Kentucky	1.3	7.2	16.4	20.0	16.0	16.0
Michigan	0.8	4.3	9.9	12.0	8.2	10.0
Minnesota	2.0	10.9	24.6	30.0	30.0	29.0
Missouri	1.5	8.0	18.1	22.0	22.0	24.0
Nebraska	1.7	9.4	21.3	26.0	26.0	26.0
New York	1.1	6.2	14.0	17.0	15.0	14.0
Ohio	0.4	2.2	4.9	6.0	6.2	7.2
Pennsylvania	0.4	2.2	4.9	6.0	5.5	5.0
South Dakota	2.5	13.4	30.4	37.0	37.0	33.0
Texas	2.0	10.9	24.6	30.0	28.0	28.0
Wisconsin	0.9	5.1	11.5	14.0	14.0	12.0
Other States	1.5	8.3	18.0	23.0	26.7	20.0
U.S. Totals	1.4	7.6	17.2	20.9	21.3	20.0

Appendix 2, Table 4. Acres Planted to *Bt* Corn

State	1996	1997	1998	1999	2000	2001
Colorado	20,000	118,343	290,599	369,000	378,000	336,000
Illinois	102,667	567,467	1,218,216	1,512,000	1,568,000	1,417,000
Indiana	26,133	149,467	333,285	406,000	410,400	424,800
Iowa	211,667	1,103,810	2,565,313	3,025,000	3,075,000	3,094,000
Kansas	43,333	258,762	640,302	819,000	897,000	891,000
Kentucky	17,333	91,924	213,434	264,000	212,800	204,800
Michigan	20,800	108,572	226,568	264,000	180,400	220,000
Minnesota	150,000	760,001	1,797,771	2,130,000	2,130,000	2,001,000
Missouri	38,867	214,972	478,585	583,000	90,200	96,000
Nebraska	147,333	837,448	1,878,219	2,236,000	2,210,000	2,132,000
New York	13,033	71,983	157,695	195,500	147,000	154,000
Ohio	12,000	82,514	174,852	207,000	220,100	244,800
Pennsylvania	5,800	33,657	76,344	90,000	85,250	75,000
South Dakota	98,667	508,838	1,184,559	1,332,000	1,591,000	1,254,000
Texas	42,000	217,143	591,048	585,000	588,000	448,000
Wisconsin	36,400	195,067	425,226	504,000	490,000	408,000
Other States	126,945	654,002	1,530,900	1,652,780	2,676,675	1,825,800
U.S. Totals	1,112,978	5,973,969	13,782,915	16,174,280	16,949,825	15,226,200

Appendix 2, Table 5. Average Corn Yield in Bushels per Acre						
State	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Colorado	142	146	145	142	127	138
Illinois	136	129	141	140	151	149
Indiana	123	122	137	132	147	160
Iowa	138	138	145	149	145	141
Kansas	152	143	147	141	130	132
Kentucky	124	103	115	105	130	140
Michigan	94	117	111	130	124	92
Minnesota	125	132	153	150	145	129
Missouri	134	115	114	97	143	136
Nebraska	143	132	145	139	126	138
New York	103	110	114	101	98	95
Ohio	111	134	141	126	147	143
Pennsylvania	119	98	111	70	127	94
South Dakota	100	96	121	113	112	116
Texas	112	138	100	129	124	115
Wisconsin	111	132	137	143	132	128
Other States	105	105	110	110	112	112
U.S. Totals	127.1	126.7	134.4	133.8	137.1	136.3

Appendix 2, Table 6. Bushels Produced on Acres Planted to *Bt* Corn at State Average Yields						
State	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Colorado	2,840,000	17,278,069	42,136,797	52,398,000	48,006,000	46,368,000
Illinois	13,962,667	73,203,248	171,768,400	211,680,000	236,768,000	211,133,000
Indiana	3,214,400	18,234,945	45,660,100	53,592,000	60,328,800	67,968,000
Iowa	29,210,000	152,325,815	371,970,313	450,725,000	445,875,000	436,254,000
Kansas	6,586,667	37,002,977	94,124,394	115,479,000	116,610,000	117,612,000
Kentucky	2,149,333	9,468,159	24,544,910	27,720,000	27,664,000	28,672,000
Michigan	1,955,200	12,702,866	25,149,092	34,320,000	22,369,600	20,240,000
Minnesota	18,750,000	100,320,066	275,058,963	319,500,000	308,850,000	258,129,000
Missouri	5,208,133	24,721,731	54,558,656	56,551,000	12,898,600	13,056,000
Nebraska	21,068,667	110,543,158	272,341,784	310,804,000	278,460,000	294,216,000
New York	1,342,433	7,918,119	17,977,217	19,745,500	14,406,000	14,630,000
Ohio	1,332,000	11,056,922	24,654,090	26,082,000	32,354,700	35,006,400
Pennsylvania	690,200	3,298,402	8,474,151	6,300,000	10,826,750	7,050,000
South Dakota	9,866,667	48,848,489	143,331,603	150,516,000	178,192,000	145,464,000
Texas	4,704,000	29,965,734	59,104,800	75,465,000	72,912,000	51,520,000
Wisconsin	4,040,400	25,748,817	58,255,989	72,072,000	64,680,000	52,224,000
Other States	13,329,190	68,670,225	168,399,000	181,805,800	299,787,600	204,489,600
U.S. Totals	140,249,957	751,307,741	1,857,510,258	2,164,755,300	2,230,989,050	2,004,032,000

Appendix 2, Table 7. Average ECB Percent Yield Reduction						
State	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Colorado	0.130	0.130	0.130	0.130	0.130	0.130
Illinois	0.183	0.052	0.024	0.019	0.025	0.115
Indiana	0.086	0.045	0.022	0.098	0.050	0.074
Iowa	0.048	0.022	0.010	0.007	0.008	0.032
Kansas	0.043	0.024	0.011	0.008	0.008	0.033
Kentucky	0.065	0.038	0.013	0.033	0.018	0.040
Michigan	0.053	0.028	0.004	0.006	0.008	0.018
Minnesota	0.061	0.025	0.011	0.007	0.009	0.050
Missouri	0.142	0.049	0.025	0.025	0.025	0.113
Nebraska	0.080	0.045	0.010	0.010	0.020	0.050
New York	0.024	0.014	0.007	0.009	0.009	0.019
Ohio	0.070	0.037	0.012	0.044	0.019	0.065
Pennsylvania	0.019	0.014	0.007	0.009	0.009	0.019
South Dakota	0.091	0.029	0.012	0.014	0.019	0.061
Texas	0.130	0.130	0.130	0.130	0.130	0.130
Wisconsin	0.076	0.034	0.005	0.015	0.015	0.041
Other States	0.056	0.024	0.014	0.009	0.009	0.031
U.S. Totals	0.080	0.043	0.026	0.034	0.030	0.060