When Does It Pay To Plant *Bt* Corn?
Farm-Level Economic Impacts of *Bt* Corn, 1996-2001

The ECB Numbers Game

Surprising Variability in *Bt* and Conventional Corn Yields

Price -- A Poor Indicator of Performance

A Consequential Choice: Farm-Level Economic Impacts of *Bt* Corn, 1996-2001

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November, 2001

This report summarizes for farm community audiences the major findings of a longer technical report by Dr. Benbrook entitled "The Farm-Level Economic Impacts of *Bt* Corn from 1996 through 2001: An Independent National Assessment" (hereafter called the "Technical Report"). Readers interested in methodological details and fuller information on data sources should refer to the "Technical Report" that is published in its entirety on the IATP website at http://www.iatp.org/, as well as on Ag BioTech InfoNet at http://www.biotech-info.net/*Bt*_farmlevel_IATP2001.html

Later this month look for a second report on *Bt* corn, this one focusing on farm-sector wide impacts of this technology. It addresses the distribution of direct and indirect costs and benefits, identifies winners and losers, and projects longer-run implications.

When Does It Pay To Plant *Bt* Corn?
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Introduction and Summary

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 first planted in 1996.

Corn farmers have now planted over 70 million acres of *Bt* corn, a testament to farmers' openness to new technology. It is amazing that so many acres of *Bt* corn have been planted without a credible, independent national assessment of farm-level economic impacts. This report presents the major findings and conclusions of a longer "Technical Report" (accessible at http://www.biotech-info.net/*Bt*_farmlevel_IATP2001.html), and offers food for thought as farmers make their corn seed choices for next year's crop.

Bt corn is genetically engineered to express the protein-based toxins of *Bt* in plant tissues for the control of two Lepidopteran insects, the European Corn Borer (ECB) and the Southwestern Corn Borer (SWCB). The chance to cash in on the proprietary technology behind *Bt* corn and other GMO crops created such a tempting target for pesticide companies that they simply bought all the major players in the corn and soybean seed industries. Merger-mania in the 1990s has now transfixed a once farmer friendly and independent seed industry into operating divisions within the agricultural or crop protection divisions within transnational chemical-energy-agriculture conglomerates.

For farmers accustomed to looking down the road to their seed dealer-neighbor for new genetics, reliable information and a fair deal, it is, put simply, a whole new ball game.

Bt Corn in Historical Perspective

The fact that *Bt* corn can and sometimes does increase yields 20 to 30 bushels per acre in the face of heavy ECB/SWCB pressure is indeed a remarkable technological achievement. The yield boost on some of the acres planted to *Bt* corn each year more than justifies its added cost to individual farmers. But through the 2001 season, American farmers have paid at least $659 million more for the chance to plant over 70 million acres of *Bt* corn. Farmers are not the only ones wondering just how often this added investment has actually paid off.

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 jump in per acre seed expenditures is by far the biggest in history linked to a single new trait in corn hybrids.

If spending more dollars per acre is an accurate measure of added value to the farmer, then *Bt* corn is hands-down the most dramatic breakthrough ever in corn breeding technology. The hybridization of corn is the other once-new technology that clearly and dramatically advanced corn genetics. The emergence of hybrid corn has increased per acre seed expenditures three- or four-fold, but this increase has occurred incrementally over nearly six decades and has been accompanied by more than a doubling of average seeding rates and more than a tripling of average corn yields.

For decades the added expense associated with corn hybrid technology has proven a solid investment for farmers, returning year-in and year-out about $3.00 for every added dollar spent on seed. As the tables in this report show, *Bt* corn has not come close to keeping pace in returning value to the farmer. What ***would*** it take to keep pace? About 15 bushels more per acre of seed sold, with corn selling for around $2.00 a bushel, would earn the farmer $30.00 more in income, three dollars for each added dollar spent on *Bt* corn seed.

In fact, the economic benefits of *Bt* corn have not even covered added expenses when averaged across all acres planted over the last six crop years.

Why then the uninterrupted, steady-stream of positive news in the farm community about the yield and economic benefits of *Bt* corn? The preponderance of happy news stems in part from effective, well-funded industry PR and advertising. Engineered and/or paid for news has dominated coverage for a second reason -- the dearth of credible, independent information on the impacts of *Bt* corn, not just on selected acres but on the average acre planted, everywhere.

How common are *Bt* corn success stories, especially in contrast to cases and acres where the technology just broke even or perhaps bombed? While the farm press rarely focuses on fields where conventional, often far cheaper hybrids out-perform *Bt* varieties, it is clear from farmer-controlled independent seed trials and university research that this other sort of success story is actually common, if not typical, across the Corn Belt.

Report Organization and Major Findings

The economic return to any technology marketed, or practice adopted, to control the ECB/SWCB is driven by the frequency of ECB/SWCB infestations, how widely the insects occur, insect population dynamics throughout their multi-stage lifecycle, and a whole host of biotic (like natural predators and corn plant defenses) and abiotic (cold weather and hard rains) factors.

In the section entitled “The ECB Numbers Game,” we boil all these complex factors down into some simple rules-of-thumb, equations, and calculations, much like those contained in many land grant university ECB/SWCB pest management bulletins, models, and reports (see the Appendix for several examples). We applied these tools as accurately as possible across all major corn producing states for 1996-2001, resulting in state-by-state estimates of the extra bushels of corn harvested on acres planted to *Bt* corn.

When we located state-level data on ECB numbers in a given year and estimates of yield impacts per ECB per plant, we incorporated them directly into the calculations. When assumptions had to be made or gaps in data filled, we relied on data from nearby states, other years, and the judgment of recognized experts in corn Integrated Pest Management (IPM). Our method and assumptions were purposefully conservative in order not to underestimate the value of *Bt* corn. For example –

- We assumed that ECB population surveys carried out late in the fall, after corn harvest, produced numbers comparable to mid- and late-summer when corn plants are vulnerable to second-generation ECB/SWCB feeding damage. In most fields (clearly not all) and on average, fall and overwintering ECB/SWCB population surveys tend to overestimate populations of second-generation insects actively feeding on corn plants in mid to late summer, when the plants remain vulnerable.

- When estimating second-generation yield losses per ECB/SWCB per plant, we did not adjust corn yields for first generation ECB/SWCB feeding damage.

- This report assumes *Bt* corn is 100 effective in avoiding ECB/SWCB losses, when a figure of 95 percent effective is more realistic and has been used by other analysts.

- We assumed each added bushel of corn harvested on a field planted to a *Bt* hybrid delivered to the farmer the full market price of corn, when in fact each incremental bushel harvested increases some agronomic (i.e., fertilizer) and harvest costs (combining, drying, storage), amounting to perhaps $0.15 to $0.25 per bushel.

- We did not calculate the cost of compliance with *Bt* corn refuge requirements, nor any added costs associated with storage, marketing, or GMO-testing of harvested corn.

“The Incremental Cost of Planting *Bt* Corn” section provides an average estimate by year of the added costs of growing *Bt* corn compared to otherwise well-adapted conventional varieties. The estimates of added cost per acre are multiplied by acres planted by year and by state to quantify the total added farmer expenditures on *Bt* corn seed.

One surprising finding emerges – 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 introduction of *Bt* corn has clearly not suspended the laws of supply and demand as factors driving movement in the price of seed corn. In fact, the limited supply of some newly introduced *Bt* varieties, especially in some maturity groups where few other *Bt* hybrids were available, may have triggered price inflation that is, in retrospect, hard to justify in terms of harvested yields. Likewise, the unexpected rush to plant *Bt* hybrids in 1997, 1998, and 1999 must have placed downward pressure on the prices of many overstocked conventional hybrids, indirectly creating some real bargains. This market dynamic also heightened the performance bar for fields planted to higher-price conventional and *Bt* hybrids.

The section entitled "The Performance and Price of Top Conventional and *Bt* Corn Hybrids" shows that the linkage between seed price and yield performance is surprisingly hit-and-miss, especially in years or regions where ECB/SWCB populations do little or no appreciable damage to corn plants. Tables in this section show that there are real seed bargains out there for farmers, whether a field is planted with conventional or *Bt* varieties. There are also some real dogs – high-prized hybrids that just don't cut it, with or without significant ECB/SWCB pressure.

Indeed, most independent corn varietal trials uncover a few amazing bargains – varieties that performed as well as and sometimes better than any other variety, yet cost $10 to $20, even $30 ***less*** per acre than other high-yielding varieties. Between the impact of varietal choice on yields and differences in seed costs, the selection of corn seed can shift profits up or down by $20 to $40 per acre, and sometimes by as much as $50.00 or more per acre.

These findings lead to a key conclusion, an intriguing question, and a key lesson for farmers –

> ***Year to year across all routine management decisions, the choice of corn seed offers perhaps the greatest opportunity to improve per acre profit performance.***
>
> ***If corn growers are not paying for yield potential when buying premium, high-priced varieties, just what are they paying for?***
>
> ***Time spent studying trustworthy varietal trial data collected in your area is time well spent.***

Our findings highlight strategies and factors that farmers should keep in mind as they study corn seed choices:

- ***Do not assume*** the newest and most expensive varieties are the most likely to produce the highest yields.

- ***Do not assume*** lower-cost varieties lack the genetics to produce top yields. University and independent seed trials show over and over that they do; your challenge is to figure out when and where and what you can do to tip the odds in your favor.

- Focus on minimizing risk by selecting well tested, proven hybrids with traits matched to your soil, climate and agronomic system.

- Look for seed bargains that will help you maximize per acre profits, not yields. Leave the quest for county yield records to those who can afford to push yield goals at the expense of profit margins.

- If new and costly seed technology seems promising on your farm, try out a new variety in a small, representative production field. Whenever you can, plant a *Bt* variety alongside a closely matched conventional one, so you can gauge for yourself how well each does under various circumstances.

- Use *Bt* corn refuge acres as your own private experimental plots as you search for the most profitable conventional hybrids for your farming conditions.

Farm-Level Economic Impacts of *Bt* Corn

The last step in this report's analysis quantifies *Bt* corn's aggregate impact on farm-level profits by state and nationally. We do this by calculating the total economic benefits from "yield losses avoided" in each of the last six years, and subtract from this dollar value our earlier estimate of total added seed costs. Both our estimates of benefits and costs are based on the most complete data and best methods available.

The bottom line is clear and negative – farmers have spent about $659 million more on *Bt* corn seed from 1996-2001, while harvesting about 276 million more bushels worth some $567 million, for a net loss of $92 million. On average, farmers have harvested about 3.9 more bushels per acre planted to *Bt* corn, but lost $1.31. If the yield bump had been about another bushel greater, or 5 bushels per acre, *Bt* corn would have been, on average, a wash at the farm-level.

The investment in *Bt* corn has paid off for farmers in three years (1996, 1997 and 2001), yet it has resulted in losses in another three (1998, 1999, and 2000). *Bt* corn delivered by far the greatest net benefits in 2001 – about $93 million (increased value of corn harvested, $231.6 million; added cost of *Bt* seed, $138.6 million).

We included 2001 estimates despite the lack of final corn production, market price, and ECB/SWCB data for two reasons. First, our goal is to provide the most complete assessment possible of the impacts of *Bt* corn technology to date. Second, leaving out 2001 estimates would have unfairly biased our results against *Bt* corn since ECB/SWCB population levels went up dramatically in several states in 2001, following three straight years of markedly lower-than-average population levels.

Can and should the data and model supporting this report's estimates be improved? Surely, yes and yes. As more complete and sophisticated data are incorporated in future studies of this time period, will bottom line results change dramatically? Not likely. Still, people will argue with some aspect or another of our estimates and findings.

Some GMO skeptics will say we have overestimated benefits, others will argue we underestimated them. Both sets of critics are no doubt correct in one detail or another, but on balance, the major findings reported herein will likely stand the test of time as more detailed research is completed and reported.

One thing is crystal clear -- farmers can and should be provided better methods to guide efforts in managing the ECB and SWCB. The key to improved ECB/SWCB management is sharper understanding of the linkages between these pests, crop genetics, agronomic systems, and yields. Such new insights will improve the accuracy of cost-benefit assessments of *Bt* corn and related ECB/SWCB technologies and will also lead to better tools to help farmers make profitable management choices, a goal that everyone claims to support.

As a scientific accomplishment *Bt* corn may well deserve its billing as one of the most dramatic breakthroughs ever in corn genetics. But in terms of farm income, it has been a dud for farmers collectively in its first six-years on the market. Granted, six years is too short a time period to take the full measure of such a major new agricultural technology, especially one as novel and contentious as *Bt* corn.

Over time the farm sector will learn how to make more effective use of this technology, price premiums should narrow, and the performance of *Bt* hybrids is also likely to improve. These factors should lower added costs and enhance benefits, improving the *Bt* corn bottom line. But other factors may erode it.

It remains to be seen whether resistance can be prevented in ECB and SWCB populations and whether physiological or soil microbial community problems will surface. Better, cheaper, less invasive alternatives may emerge for managing ECBs and SWCBs, reducing farmer interest in today's *Bt* corn technology despite lower costs and improved performance.

Public concerns, market jitters, and better options for farmers may soon push *Bt* corn engineered to control the ECB and SWCB to the sidelines. The pressing need to open the corn seed market to hybrids engineered to express toxins targeting the much more damaging corn rootworm complex may accelerate the day when the seed industry has to make a choice. The technical hurdles the industry will face in developing and proving the safety of corn plants expressing two *Bt*-based toxins targeting two major categories of corn insects will likely prove unmanageable on many fronts.

Hopefully lessons learned in the commercial introduction and planting of today's *Bt* varieties will pave the way for a smoother ride for the next generation of insect-resistant corn, whether developed through genetically engineered or conventional breeding techniques. Farmers, and those who profess to represent farmers in the public arena, should pay closer attention to whether the next wave of "advanced" corn genetics will truly benefit farmers or whether, in the end, it will just transfer to the pesticide-biotech-seed industry another chunk of income that used to stay on the farm.

Doane Data Provides Key New Insights

Much of the basic information in this report on the corn seed market comes from analysis of Doane Marketing Research, Inc. corn seed data covering 1998-2000. Doane corn seed data are reported by variety/company, type of variety, and Doane's "Maturity Group". (Doane analysts classify all corn varieties into one of eleven "Maturity Groups" based on relative maturity ratings). The data purchased by Benbrook Consulting Services (BCS) includes acres planted, units planted (a "unit" is a bag of seed containing about 80,000 kernels, enough to plant 2.5 to 3 acres), average retail prices per unit, average discounts, and net prices (retail prices minus discounts).

Doane corn seed data for 1998-2000 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 sold, along with 2,320 *Bt* corn hybrids. There were, accordingly, 6.6 conventional varieties on the market for each *Bt* hybrid.

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 the corn seed market for 1998-2000, drawing on Doane data. It reports the acres planted and units sold by type of variety, as well as acres planted per unit and average seeding rates. This is the first time this basic descriptive information on the corn seed market has been included in a public report.

Table1. 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.

BCS purchased the proprietary Doane data under a license precluding release of the raw data or disclosure of information that would make it possible to reconstruct the raw data. This is why we are unable to identify the specific corn variety covered on a specific line in many of the tables that follow.

We apologize to farmer-readers for having to leave out such key pieces of information. Farmers can overcome this limitation in researching their 2002 seed choices by collecting the results of credible varietal trials carried out in their areas, focusing on yields of varieties in the relevant maturity group. Current prices for the most well-adapted *Bt* and conventional varieties can then be gathered from local seed dealers and the Internet, in effect constructing a farm-specific "corn variety comparison table" much like Tables 9-12 herein. Farm-specific tables should also include varieties planted in recent years on the farm or nearby, if and to the extent reliable yield and price data are available.

The ECB Numbers Game

How can farmers predict whether the added cost of a *Bt* corn hybrid will pay off as they contemplate seed selection choices for crop year 2002? Equally important, how can farmers tell if their added investment in *Bt* corn in 2001, or earlier years, paid off?

The better a farmer becomes at the ECB numbers game, the more likely that their answers to these key questions will be accurate and translate into management decisions that consistently boost per acre profits.

Projecting ECB/SWCB Losses per Borer per Plant

Looking back, farmers can assess the performance of *Bt* hybrids by carefully monitoring yields of *Bt* and conventional varieties planted on otherwise similar fields. The key question is did the average yield advantage on acres planted to *Bt* corn pay for the added cost of *Bt* seed, given other costs entailed in growing and marketing an added bushel of corn from a field of *Bt* corn, and the price farmers are able to sell their corn for?

Looking ahead, the ECB numbers game entails assessment of the probability that ECB/SWCB levels in a given field next year will exceed the threshold above which *Bt* corn will pay off. In most states, that level is between 0.5 and 1.5 first-generation ECBs per plant, or somewhat higher levels of second-generation insects.

What does "1.0 ECB per plant" mean, given that in any given field, first- or second-generation population levels are known to fluctuate widely?

It is a full-field average. How can a farmer estimate this number? Well, if time and money were unlimited, a farmer or hired scout would sample every single corn plant in a field and count all ECB larva on all plants. The total number of ECB larva found would then be divided by the number of plants, equaling the number of ECBs per plant.

One field with 1.0 ECB per plant might have an average of two ECBs on each of the one-half of plants infested; another field might have only one-quarter of the plants infested, but an average of four larva per plant.

It is obviously far too costly to sample every plant in a field, so Integrated Pest Management experts at each land grant university have developed ECB/SWCB field sampling protocols that entail, for example, collecting 25 plants in four locations within a field. The total number of larva found would then be divided by 100, equaling the number of ECBs per plant, a key parameter then used to estimate percent yield losses.

State-by-state estimates of the damage from an average 1.0 ECB per plant are presented in Table 2. "Damage" is expressed as a percent of corn yield lost in a field with an average of 1.0 larva per plant (or, 100 ECB per 100 plants). For example, in Illinois fields with one larva of first-generation ECB per plant, the University of Illinois model projects a 4.5 percent loss in yield; if three larva were found on average, the projected yield loss would be 13.5 percent; if 0.5 larvae were present, yields would be expected to be reduced about 2 percent, on average. It must be stressed that these percent yield losses are averages over many years, at a given infestation level. In some years, weather conditions hammer ECBs and actual yield losses will be less than expected, whereas in other years, a variety of factors can actually increase the damage caused by 1.0 ECB per plant.

Table 2. 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.

In estimating the benefits of *Bt* corn in states lacking published estimates of first generation ECB/SWCB losses, we chose 5.5 percent as our estimate, a level toward the high-end of the eleven state estimates in Table 2, and another assumption that may tend to marginally overestimate the benefits of *Bt* corn.

The range of estimates caused by second-generation ECB varies somewhat more widely than first generation loss estimates. In states lacking a published model to predict second generation ECB/SWCB damage, we assume an average yield loss of 4 percent per ECB, again toward the high-end of the estimates for the ten states reporting values in Table 2.

Many factors can and do impact actual yield losses experienced in a given field from a given population of ECBs/SWCBs. In years with otherwise perfect growing conditions, plants can sustain a relatively higher level of ECB/SWCB damage with minimal yield loss. 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).

Remember though that such inclement weather conditions, and many other adverse/beneficial biotic factors, will usually also have an adverse/beneficial impact on yields regardless of the variety planted. This is one of the many reasons why the ECB numbers game is complex and entails interpreting and marginally shifting the odds, since no farmer controls the weather or the many other factors than can and do drive ECB/SWCB populations and damage up or down in a given year or field.

In most years out of ten, good managers avoid the levels of losses predicted in Table 2 by finding subtle ways to tip the odds in the favor of the corn plants growing in their fields. They limit potential and actual yield losses at the margins by blunting the impact of risk factors and yield robbers like a wet spring or compaction, or a flush of late-season foxtail. Some use timely, targeted spot applications of insecticides to deal with unusual spikes in ECB/SWCB populations. Others choose to lengthen rotations or use strip-cropping systems that increase the population of predatory insects in cornfields, some of which are usually more than willing to feed on ECBs/SWCBs.

Top-notch managers change to their advantage both the equations and the parameters in the ECB numbers game. The losses they incur are consistently less than what university data and models would predict. Conversely, less skilled or inattentive managers often make matters worse by placing other kinds of stress on corn plants, exacerbating ECB/SWCB pressure and/or damage and as a result, often experience greater than average yield losses. They are, in short, consistent victims in the ECB numbers game, in that things all-too-frequently work out worse than expected.

It is true that *Bt* corn greatly simplifies the management of ECBs, but simplicity does not guarantee yield increases on acres planted to *Bt* varieties. This technology also heightens other sorts of risks and raises costs, so in the end profits may and often do suffer.

In deciding whether *Bt* corn is a good investment, there is a clear trade-off between management skill and effort and the cost of seed. Farmers who know and understand ECB/SWCB population dynamics in their area, and are willing to experiment with non-*Bt* control options, can almost surely find ways to more profitably deal with ECB/SWB pressure than planting most of their acreage every year to *Bt* corn. Less knowledgeable or unmotivated managers, on the other hand, may be better off to invest in *Bt* corn annually on most of their acreage as a form of ECB/SWCB crop insurance.

ECB Population Levels

Over the years, thousands of person-years have been spent collecting field data on ECB/SWCB populations. Some states are able to report ECB population levels since the 1940s. Other states never bothered to collect much ECB data, or stopped collecting ECB data years ago. Still, there is enough data across the major corn producing states to compile a reasonably good approximation of ECB levels and damage since 1996. (See Appendix 1, Table 1 in the "Technical Report" for a review of available ECB data by state).

In a nutshell, if ECB/SWCB populations in your area or on your farm are typically well below threshold, and markedly exceed thresholds in only one or two years per decade, *Bt* corn is unlikely to pay when the impact on your profits is averaged over several years.

But if population levels are at or near thresholds in most years, and well above them in three or more years out of ten, you should be actively managing population levels. The planting of *Bt* corn should be one of the options you explore, but surely not your only response.

In managing pests, success in the long run depends on spreading around the control burden like a good pitcher mixes fastballs, changes, and sliders. Too much reliance on any technology or practice – whether chemical, genetic, biological, or cultural – gives the upper hand to pests who can and almost always do find a way to adapt. Evolution remains a powerful and ubiquitous force that all new technologies, including *Bt* corn, must come to terms with.

Table 3 presents our estimates of first-generation ECBs per plant for 1996-2001 by state and Table 4 covers second-generation ECB larva. The numbers in Tables 3-4 rely on hard data when available from state-level surveys.

Table 3. 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.

Table 4. 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.						

Note the generally higher ECB population levels in the Southern and Western Corn Belt. These numbers are intended to reflect combined damage triggered by both the ECB and the SWCB. Crop damage in these areas 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.

Note also the generally higher population levels in 1996 and 2001, the two worst years for ECB/SWCB pressure since the introduction of *Bt* corn, especially compared to 1998-2000, three years with well-below-normal ECB/SWCB levels.

Estimating ECB/SWCB Population Levels From Limited Survey Data

Only a few states report both first and second-generation ECB population levels and no state has good data for all six years covered in this report. Most states use fall overwintering surveys as representative of second-generation populations, when in reality these numbers reflect the number of borers surviving at the end of the season rather than the number actively damaging plants at the height of the growing season.

In states reporting fall or second-generation ECB levels only, we used the relationship between first and second-generation population levels in other states to help approximate first-generation levels, along with any first-generation data available from nearby states.

For several states, data were available for two to four years out of the six, requiring extrapolation of data from nearby states and/or other years. In some states with modest corn acreage there was little or no data available.

Extension bulletins and reports were reviewed to gain insight into trends in population levels. In general, the levels in Tables 3-4 reflect long-term trends and generally accepted differences across regions. The number of years with relatively high pest pressure (two) in contrast to relatively low pressure (three) also tracks historical data.

Estimates were also shaped by anecdotal reports and comments by land grant entomologists regarding ECB/SWCB populations and feeding damage in a given year. While many states do not conduct nor report formal survey data, all states have corn pest management specialists active in the field each year who issue informal reports and contribute to experiment station publications that summarize the view of experts regarding ECB/SWCB population levels as each production season unfolds.

Projecting the Yield Gain on Acres Planted to *Bt* Corn

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

First, the acreage planted to *Bt* corn must be approximated by state, drawing on USDA, EPA, and other data. Table 5 reports our estimates for 1996-2001. (See the "Technical Report" for the methods and data sources relied on in producing Table 5).

Table 5. 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. Total	1,112,978	5,973,969	13,782,915	16,174,280	16,949,825	15,226,200

The number of bushels produced on the acres in Table 5 is easily calculated by multiplying acres planted by average state corn yields. ECB/SWCB losses avoided on acres planted to *Bt* corn are then estimated based on percent reductions in the bushels produced by state and year. Table 6 combines first- and second-generation ECB/SWCB damage estimates and reflects best available estimates of population levels (see Tables 3 and 4) and yield losses per ECB per plant (Table 2).

Table 6. Average ECB Percent Yield Reduction						
State	1996	1997	1998	1999	2000	2001
Colorado	13%	13%	13%	13%	13%	13%
Illinois	18%	5%	2%	2%	3%	12%
Indiana	9%	5%	2%	10%	5%	7%
Iowa	5%	2%	1%	1%	1%	3%
Kansas	4%	2%	1%	1%	1%	3%
Kentucky	7%	4%	1%	3%	2%	4%
Michigan	5%	3%	0%	1%	1%	2%
Minnesota	6%	2%	1%	1%	1%	5%
Missouri	14%	5%	2%	2%	2%	11%
Nebraska	8%	5%	1%	1%	2%	5%
New York	2%	1%	1%	1%	1%	2%
Ohio	7%	4%	1%	4%	2%	7%
Pennsylvania	2%	1%	1%	1%	1%	2%
South Dakota	9%	3%	1%	1%	2%	6%
Texas	13%	13%	13%	13%	13%	13%
Wisconsin	8%	3%	0%	1%	1%	4%
Other States	6%	2%	1%	1%	1%	3%
U.S. Total	8%	4%	3%	3%	3%	6%

The Incremental Cost of Planting *Bt* Corn

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 for some varieties, a pure price premium. The "tech fee" is charged by the companies holding patents on *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.

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 or less than the tech fee. One company – Aventis Crop Sciences, the source of StarLink corn resistant to the Aventis herbicide Liberty (glufosinate) – did not charge a tech fee for its *Bt* trait and instead profited from increased sales of Liberty herbicide.

In its assessment of *Bt* corn benefits, 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.

One fact is clear. *Bt* corn seed technology fees are "in play" and they have come down some since 1996-1998. Some companies have announced a change in their pricing structures for crop year 2002 whereby tech fees will be built into the price of seed at the grower level and not broken out in price sheets and invoices, as is typically now the case. This will make it harder for farmers (and analysts and regulators) to track trends in tech fees and price premiums.

Establishing the *Bt* Corn Price Premium

Three methods were used to quantify *Bt* corn price premiums drawing on Doane Marketing corn seed data for 1998-2000.

First, average annual corn seed prices per unit were computed for all 17,000 plus conventional and *Bt* varieties across three years within the eleven Doane maturity groups. By year, we calculated for conventional and *Bt* hybrids the average-retail price, the average discounts offered, and the average-net price (retail price minus discounts). This computation required several steps in order to weight the price of each variety by its marketshare within a maturity group, a step that is necessary to produce accurate estimates based on the actual acres planted of different varieties.

We then calculated average prices for all *Bt* and conventional varieties by year, weighted by the acres planted in each maturity group. This step assured that the greatest weight was given to maturity groups accounting for the largest share of acres planted in the overall estimate of price premiums. Table 7 reports the results.

Table 7. 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	Premium per Unit: 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. Counting discounts for early purchase, volume sales, and bundling, the average net price premium was $27.48, a level close to the commonly reported size of the technology fee – $26.00.

Table 8. 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

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.

Method two compares prices and premiums across nineteen pairs of *Bt* and similar conventional hybrids offered for sale by Pioneer Hi-Bred International. Table 8 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 and price premiums is surprising. The most expensive *Bt* variety is over $50.00 more per unit than the least expensive *Bt* varieties. The price premium for the most expensive *Bt* variety in Table 8 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 of seed for four matched pairs of Pioneer varieties, and under $15.00 in three cases.

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 sold by the same company in the same maturity group. In four cases there was no matching variety for sale in 2000, so Table 9 reports the results for twenty matched pairs of *Bt*-conventional varieties. On average, the retail price premium was $25.75 and the net price premium was $26.57. 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.

Table 9. 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.

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.

The Performance and Price of Top Conventional and *Bt* Corn Hybrids

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 $2.00 per bushel, a farmer would need to harvest nine bushels more per acre to cover the added cost of seed.

Actually, the farmer will need to harvest yield increases on the order of 10-11 bushels per acre to break even, since there will be higher variable costs associated with the increased yields (fertilizer, drying, harvest and handling, storage).

Three 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 covers the results of yield trials in Danville Illinois, Council Bluffs Iowa, and Oxford Indiana conducted by independent contract research firms (Horstmeier, 2001). The results are reported in Table 10.

The yield information in Table 10 is from the 2001 *Farm Journal* corn seed 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 by a remarkable 33.6 bushels another variety sold for the same price per unit.

The four top-yielding varieties produced over 190 bushels per acre and sold for $98.00 to $92.02 per unit. Their yields were at least 20 bushels more than the high-cost, herbicide tolerant (HT) variety that sold for $116.73 per unit. The top variety produced about $40.00 more gross revenue than the high-cost, HT variety. Since corn herbicide costs per acre are on the order of $20.00 to $30.00, it is not possible that lower weed management costs made up for the loss in income.

The top-yielding variety in the 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, 17 bushels less than the top-performing variety.

The best conventional variety produced 168 bushels and cost $70.05 per unit. Two high-cost *Bt* varieties were over $132.00 per unit -- $21 dollars more per acre

Table 10. Price and Yields of Selected Varieties in Three Locations Ranked by Yield, *Farm Journal* 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.

planted – and produced more than ten bushels less, for a per acre profit difference of over $40.00!

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 11 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 included 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 $19.00 more per acre. The high-priced variety also contained the *Bt* gene but was the poorest performer, yielding 129 bushels.

Table 11. 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.

Farmers planting the top-performing conventional variety earned about $24.00 more per acre in revenue and spent $19.00 per acre less on seed, for a profit gain of $43.00 per acre compared to the farmers growing the high-cost *Bt* variety.

The Danville and Council Bluff differences in per acre profits are eye opening given the narrow margins in the corn business today.

Bt varieties performed better 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. Tables 12 and 13 report F.I.R.S.T. results for the central and northern parts of Iowa in 2000.

Table 12. 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.

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 came in at number two in yield, at 179 bushels per acre.

Table 13. 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.

The best conventional variety cost about $5.90 less per acre than the top *Bt* variety and produced eight less bushels. Here, the *Bt* variety increased profits per acre by about $6.00. Still, several of the top conventional hybrids were more profitable for farmers than all but two 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 – 20 bushels at $2.00 plus $15.50 per acre more for seed, equaling a $55.00 difference in per acre income.

In North Iowa, 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 $15.00 more per acre, for a slight loss in farmer-profit. The difference in profit was more dramatic compared to the high-cost *Bt* variety, which came in 27th in yield at 153 bushels and cost $132.90, for a profit difference of about $49.00 per acre.

Forces Driving Seed Corn Prices

Several factors 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 demand for corn seed in different maturity groups, and hence prices.

The relatively high price paid for some *Bt* varieties likely reflects the fact that quantities were limited relative to demand, especially in the year new varieties were introduced. Likewise, the low net price paid for some varieties probably 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, especially over time. Higher-priced hybrids that earn and hold market share are typically at or near the top in yields relative to other hybrids suitable for the same area and farming system. When a new variety proves itself and offers farmers a chance to reduce seed costs while maintaining yields, farmers are rarely hesitant to switch.

Farm-Level Cost and Benefits of *Bt* Corn, 1996-2001

The total premium paid by farmers planting *Bt* corn hybrids is equal to the total number of acres planted (see Table 3) multiplied by the average *Bt* corn price premium. Over the last six years corn growers planting *Bt* varieties have paid $659 million more for their seed than would have been the case if they planted conventional varieties.

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.

Table 14. 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)

Source: Benbrook Consulting Services, 2001.

The benefits of *Bt* corn come largely from increased yields. Estimates of the average percent yield increase on acres planted to *Bt* corn were offered in Table 6. The costs and benefits of *Bt* corn appear in Table 14 for each state producing significant acreage of corn in 1996-2001. State data by year is the number of bushels saved by *Bt* corn.

The line "*Bt* Corn Price Premium" reports the added costs of *Bt* seed and the last line is the bottom line – *Bt* corn economic benefits less added *Bt* seed costs.

Nationwide in the six years since commercial introduction, *Bt* corn has increased corn production by an estimated 276 million bushels, valued at $566.8 million dollars. Farmers have paid at least $659 million more for *Bt* corn seed, resulting in a net loss of about $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 were greatest in 1998, a year with low ECB populations in most Corn Belt states and profits were greatest in 2001, a year with moderate to high ECB/SWCB population levels.

Note in 1998 that two states growing only 6.3 percent of the nation's *Bt* corn – Colorado and Texas – account for 37 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, there may be the need to segregate *Bt* corn from other grain and to carry out tests on the conventional grain in storage on a farm.

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. 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.

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 yield performance of some *Bt* hybrids is also likely to improve as more back-crosses are made and experience is gained with transformed varieties.

It remains to be seen whether resistance can be prevented in ECB and SWCB populations and whether physiological or soil microbial community problems will surface. No one can predict, either, whether world markets will warm to *Bt* corn.

Public concerns and poor economic performance on the farm may soon push *Bt* corn engineered to control the ECB and SWCB to the sidelines. Another factor may accelerate the day the seed industry backs away from ECB-*Bt* corn – the need to open the market to hybrids engineered to express toxins targeting the much more damaging corn rootworm complex.

Hopefully lessons learned in the commercial introduction and planting of today's *Bt* varieties will pave the way for a smoother ride for 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 leave them better off. It might, like *Bt* corn for the ECB, just shave another slice off per acre profits in the course of improving the profitability of seed-biotechnology companies.

Data Sources, Further Information and Literature Cited

EPA Information

Detailed EPA document, "Biopesticides Registration Action Document", on the reregistration of *Bt* crops is 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 from scientists and public interest groups is accessible at – http://www.biotech-info.net/*Bt*_rereg.html

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

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