

Impacts of Genetically Engineered Crops on Pesticide Use in the United States: The First Eight Years

By:
Charles Benbrook
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A. EXECUTIVE SUMMARY

The major genetically engineered (GE) crop varieties commercialized since 1996 in the United States have been designed to help control a damaging class of insects and simplify herbicide-based weed management systems. Over the first nine years of commercial use, 670 million acres of crops expressing GE traits have been planted, or about 23 percent of total 2,970 million acres of crops harvested across the country during this period.

Remarkably rapid and extensive adoption of GE varieties in three major crops -- corn, soybeans and cotton -- has brought enormous commercial success to the biotechnology and seed industry and reflects the popularity of this technology to row crop farmers. Still, adoption is limited to two traits in three crops that are, for the most part, either fed to animals or heavily processed. Staple crops consumed directly by people in the U.S. remain GE-free, with the exception of very limited experimental plantings.

Crops engineered to tolerate applications of herbicides, or so-called "herbicide tolerant" crops (HT), account for the largest share of GE acres. About 487 million acres have been planted since 1996, or 73 percent of total GE crop acres. HT soybeans are the most widely planted GE crop technology and account for over half the total acres planted to GE varieties since 1996. The vast majority of HT crops are engineered to tolerate glyphosate (trade name "Roundup"), a herbicide discovered by Monsanto and introduced to the market in 1972. Crops engineered to tolerate glyphosate are also called "Roundup Ready."

Corn and cotton have been genetically engineered to express the bacteria toxin *Bacillus thuringiensis*, or *Bt*. This transgenic trait allows plants to manufacture within their cells a crystalline protein that is toxic to most Lepidopteron insects. Some 183 million acres of *Bt* transgenic corn and cotton have been planted since 1996, representing 27 percent of total GE crop acreage.

Pesticide Reduction Claims are Unfounded

The debate over the costs, risks, and benefits of agricultural biotechnology has been underway for about a decade, with no end in sight. Throughout this period, biotech proponents have claimed repeatedly that today's GE crop technologies are reducing pesticide use. A comprehensive accounting of the impacts of HT and *Bt* transgenic varieties on total pesticide use demonstrates unequivocally that in the first three years of commercial use, this claim was justified. But since 1999 it has not been.

GE corn, soybeans and cotton have led to a 122 million pound increase in pesticide use since 1996. While *Bt* crops have reduced insecticide use by about 15.6 million pounds over this period, HT crops have increased herbicide use 138 million pounds. *Bt* crops have reduced insecticide use on corn and cotton about 5 percent, while HT technology has increased herbicide use about 5 percent across the three major crops. But since so much more herbicide is used on corn, soybeans, and cotton, compared to the volume of insecticide applied to corn and cotton, overall pesticide use has risen about 4.1 percent.

Pull quote – “Since 1990, suggested glyphosate rates have increased by 50% to 200% on certain weeds including ryegrass, horseweed, foxtail, barnyardgrass and waterhemp.”

Farm Journal
Spring 2004

The increase in herbicide use on HT crop acres should come as no surprise. Weed scientists have warned for about a decade that heavy reliance on HT crops would trigger changes in weed communities and resistance, in turn forcing farmers to apply additional herbicides and/or increase herbicide rates of application. The ecological adaptations predicated by scientists have been occurring in the case of Roundup Ready crops for three or four years and appear to be accelerating. Farmers across the American Midwest look back fondly on the initial efficacy and simplicity of the Roundup Ready system and many miss the “good old days.”

Reliance on a single herbicide, glyphosate, as the primary method for managing weeds on millions of acres planted to HT varieties remains the primary factor that has led to the need to apply more herbicides per acre to achieve the same level of weed control. Average applications rates of glyphosate in HT weed management systems have jumped sharply in the last few years as a result of the spread of glyphosate-tolerant or resistant maretail (also known as horseweed), shifts in the composition of weed communities, and substantial price reductions and volume-based marketing incentives from competing manufacturers of glyphosate-based herbicides.

[pull quote – “Weed shifts and herbicide resistance are a direct result of a lack of diversification in weed management systems.”

Dr. Jeff Gunsolus, Univ. of Minnesota
“Managing Weed Escapes in RR Corn”

While ecological changes are pushing herbicide use upward on HT crop acres, regulatory forces and industry innovation are edging average application rates downward on land planted to conventional varieties. S-metolachlor herbicide was registered in time for the 1997 crop season. It is a new and more biological active version of metolachlor, an older, high-rate herbicide. S-metolachlor is applied at 65 percent of the rate of original metolachlor and has reduced herbicide use by 10 to 12 million pounds per year since 1998. The Environmental Protection Agency also placed new restrictions on the most widely used corn herbicide, atrazine, triggering substantial drops in per acre application rates in 2000 and again in 2002.

As a result, the difference in the total pounds of herbicides applied per acre planted to HT crops compared to non-HT conventional varieties has increased steadily since 2000. Three factors – the emergence and spread of weeds resistant or less sensitive to glyphosate, limited supplies of conventional crop seeds in a number of popular maturity groups, and aggressive herbicide price cutting by companies seeking a larger share of the glyphosate market -- are working together to create the “perfect storm” that now threatens to undermine the efficacy of HT technology.

Add picture here of marestial resistant weed infestation – one possible source is penn state update – we have hard copy.

B. INTRODUCTION

Today’s genetically engineered (GE) crops are designed to simplify and expand the use of pesticide-based strategies for the management of common weed and Lepidopteron insect pests. Proponents of biotechnology claim that today’s GE varieties substantially reduce pesticide use, a claim not substantiated by U. S. Department of Agriculture (USDA) data and reports. Here, USDA data on the acreage planted to GE crops and pesticide use are relied on in calculating the overall impact of GE crops on the volume of pesticides applied in the production of corn, soybeans, and cotton during the period 1996-2004.

All USDA studies done to date on the impacts of GE crop technology on pesticide use have focused on the first three years of adoption, 1996-1998, and are accessible via the Economic Research Service’s “Key Topics” page on biotechnology (<http://www.ers.usda.gov/Topics/view.asp?T=101000>). Analyses by Leonard Gianessi sponsored by the biotechnology industry have projected positive impacts on pesticide use, most recently in crop year 2001, and can be accessed on the website of the National Center for Food and Agricultural Policy (<http://www.ncfap.org/whatwedo/40casesstudies.php>). No study by USDA or private analysts has estimated nor reported the impacts in recent years. This is the first comprehensive estimate of the impacts of GE crops on pesticide use over the first nine years of commercial use.

This report draws on official USDA statistics on the acreage planted to GE varieties from 1996 through 2004, coupled with USDA data on the volume of pesticides applied to corn, soybeans, and cotton. These three crops account for nearly all acres planted to GE crops in the United States. The analysis addresses the impacts of the two major types of GE traits –

- Herbicide tolerant (HT) corn, soybeans and cotton;
- *Bacillus thuringiensis* (*Bt*) transgenic corn and cotton.

Herbicide Tolerant Crops

Herbicide tolerant (HT) crops allow farmers to spray broad-spectrum herbicides over the top of growing plants, controlling most weeds while leaving crops largely unharmed. HT weed management systems are simple, flexible, and forgiving, and in most years and regions, they have been very effective, at least until recent years. Good performance coupled with ease of use explains why farmers have so enthusiastically embraced HT crops.

The economic impacts of HT crops have been complex and dynamic. In the first three years of adoption, most farmers attained adequate control of weeds with a single application of glyphosate herbicide. As Roundup Ready (RR) crops gained market share at the expense of other herbicides, the companies losing market share cut herbicide prices aggressively. By 2000, the average cost of soybean herbicides had been cut about 40 percent, saving farmers hundreds of millions per year. These savings, however, have nothing to do with the inherent efficiency of HT technology; competitive forces in a hotly contested marketplace brought it about.

In 2000 patent protection for glyphosate herbicide came to an end, allowing generic competitors to enter the market. Since 2001, the price of glyphosate has fallen steadily to about one-half to one-third the level in 1996 when HT crops were first introduced. In September 2004, Monsanto announced further price reductions for Roundup brand herbicides for crop year 2005, coupled with substantial enhancements in their incentive programs for farmers agreeing to buy Monsanto seed and apply only Monsanto-brand herbicides. This sort of bundling of inputs is an increasingly common tactic used in fiercely contested agricultural input markets and has attracted the attention of the antitrust division of the Department of Justice.

While glyphosate prices have fallen, use rates have risen, as has the need for farmers to apply additional herbicides to deal with tough-to-control grass weeds and weed species that have attained either tolerance or resistance to glyphosate. So despite dramatic, across-the-board decreases in the price of herbicides in 2002-2004, farmers are spending about the same amount on weed control because they have to spray two to three different herbicides, have to spray more times, and they are still paying a significant premium for HT seed.

Until the widespread adoption of RR crops, weed scientists had confirmed only two cases of glyphosate resistant weeds – rigid ryegrass in Australia, South Africa, and

the U.S., and goosegrass in Malaysia. Six different weeds are now resistance in multiple countries and states, and there is a long list of weeds that have developed a degree of tolerance sufficient to require applications of other herbicides. The Weed Science Society of America maintains an up to date global registry of resistance weeds. Figure X presents the current accounting of glyphosate resistance. (Glyphosate is referred to as “GLYCINE” in the figure, the name of glyphosate’s chemical family).

Figure X Current Inventory of Glyphosate Resistant Weeds

[Glycine page from www.weedscience.org] have hard copy.

***Bt* Transgenic Technology**

The other major category of GE crops has been engineered to produce one or more of several crystalline forms of the natural bacterial toxin *Bacillus thuringiensis* (*Bt*). Unlike chemical insecticides that are sprayed typically in a liquid form one to three times a season to control Lepidopteron insects, *Bt* toxins are manufactured continuously inside and throughout the plant, exposing both target and nontarget organisms feeding on the plant, or on plant roots, to *Bt* toxins. The technology is inherently prophylactic, since the plant manufactures the *Bt* toxins whether or not insect populations exceed economic thresholds (the level of pest infestation at which crop losses exceed the cost of control interventions).

When an acre is planted to a *Bt* transgenic variety, several changes often occur in the range of pest and beneficial species residing in the field. Sometimes the absence of insecticide applications targeting Lepidopteron insects creates an ecological window allowing other secondary insects to increase to potentially damaging levels. In other cases, lessened use of the generally broad-spectrum chemistry used to control Lepidopterons allows a range of beneficial arthropods to flourish in crop fields, reducing other insect problems. Sometimes both phenomena occur simultaneously, with secondary pest problems typically emerging rather quickly, followed by a gradual reduction in insect pest pressure as beneficial insect populations are established and thrive.

As a result, it is complicated to carry out a full accounting of the net impact of *Bt* varieties on insect populations and insecticide uses. There is another important factor that should be taken into account in estimating the net impact of *Bt* transgenic technology on insecticide use. The *Bt* toxin that is produced continuously in *Bt*-transgenic plant tissues is insecticide nearly identical to the *Bt* toxins that are the active ingredients in liquid *Bt* insecticide sprays. The volume of *Bt* toxin produced over a full season in a field of *Bt* transgenic plants should be calculated and then counted in estimating the impacts of *Bt* technology on insecticide use. Doing so is difficult and beyond the scope of this report, and indeed no such estimates have been disclosed or published. Accordingly, this report’s estimates of the impact of *Bt* crops on average insecticide use per acre overstate the actual impact by an amount equal to the quantity of *Bt* toxin produced by the plants produced on an average acre planted to a *Bt* transgenic variety.

C. ACREAGE PLANTED TO GENETICALLY MODIFIED VARIETIES AND PESTICIDE USE, 1996 THROUGH 2004

Commercial plantings of genetically engineered crops in the United States began in 1996. Table 1 provides an overview of the land planted to three major crops – corn, soybeans, and cotton. Genetically modified varieties of these three crops account for nearly all the acres of genetically modified agricultural crops produced in the United States since 1996. A small number of acres have been planted to genetically modified potatoes and herbicide-tolerant canola (rapeseed).

Table 1 presents the total acres planted to the three major crops from 1996 through 2004, as well as over the full nine-year period. Summary data on pesticide use on these crops are also provided including –

- Pounds of herbicides applied per acre and total pounds of active ingredients applied by crop;
- Insecticides applied per acre and totals by crop; and
- Total pounds of herbicides, insecticides, and herbicides plus insecticides applied across the three crops.

The pesticide use estimates in 2004 in Table 1 are projections from recent trends. The factors taken into account in making these estimates are discussed in part D, where pesticide use on each of the three crops is discussed and analyzed.

In the nine years since the introduction of genetically modified varieties of corn, soybeans, and cotton, the intensity of herbicide and insecticide use per acre has declined modestly on average from 2.2 pounds of active ingredients per acre to about 1.9 pounds, or by about 14 percent. Most of the reduction has been brought about by the registration and adoption of pesticides applied at markedly lower rates per acre than the older products they have displaced. Herbicide use in these crops was still dominated in 1996 by products applied at rates of 0.5 pounds to over 1.0 pound per acre. Likewise, insecticides applied at relatively high rates, sometimes up to 1.0 pound per acre, still accounted for a significant share of the corn and cotton acres treated with insecticides.

Today, low-dose chemistry accounts for the lion's share of acres treated with both herbicides and insecticides. Several products are applied at rates less than 0.1 pound per acre, and some are sprayed at rates below 0.01 pound per acre. For example, the most widely used corn insecticide in 1996 was permethrin, an insecticide then applied at an average rate of 0.12 pound per acre. The dominant insecticide applied in 2003 was cyfluthrin, a product effective at just 0.006 pound per acre. In soybean production, 27 percent of national acres in 1996 were treated with the herbicide pendimethalin at an average rate of 0.97 pounds per acre, and trifluralin was applied on 20 percent of national acres at a rate of 0.88 pounds. From 1996 to 2002, the combined percent of acres treated with these two high-dose herbicides dropped from 49 percent to 16 percent. In 2002,

sixteen herbicides were applied at average rates below 0.1 pound per acre on conventional soybeans.

Acreage Planted to Genetically Modified Varieties

Accurate data is available from the U.S. Department of Agriculture's Economic Research Service (ERS) on the percent of crop acres planted to GE varieties by State and nationally. ERS acreage estimates are based on farm-level survey data collected by USDA's National Agricultural Statistics Service (NASS). Table 2 summarizes recently released ERS data on the percent of total national crop acres planted to herbicide tolerant (HT) and *Bt* transgenic varieties of corn, soybeans, and cotton. All estimates of the acres planted to GE varieties in this report are derived from these USDA estimates of percent acres planted to GE technology, coupled with the total acres planted to each of the three major crops in Table 1. Three appendix tables present more detailed information by crop and by State on the percent of acres planted to GE varieties. Chart X shows the trends over time in the percent of acres planted to HT and *Bt* transgenic varieties.

Chart X. Trends in the Percent of National Crop Acreage Planted to Herbicide Tolerant and *Bt* Transgenic Crops, 1996-2004

[simple line chart; one line for each of the 5 trait-crop combinations; vertical axis is "Percent Crop Acres Planted" and horizontal axis is years]

Herbicide-tolerant soybeans were planted on 85 percent of national crop acreage in 2004, up 4 percent from 2003. The rate of adoption of herbicide-tolerant corn is clearly increasing at a much slower pace than in the case of soybeans. Some 18 percent of national corn acres were planted to HT varieties in 2004, reflecting an average annual growth rate of under 2 percent of national corn acres per year since commercial introduction in 1996. In contrast, the rate of growth in adoption of HT soybeans has been about four-times greater.

Bt transgenic corn varieties were planted on an estimated 32 percent of total crop acres in 2004, up modestly from 2003. Since 1998, the percentage of corn acres planted to *Bt* corn has varied from 19 percent to 32 percent. Adoption went down in two years since 1998 and has risen in four years. *Bt* cotton was adopted on 12.7 percent of national acres in its first year of introduction and now is planted on about 46 percent of total acres.

Table 3 presents the national acres of corn, soybeans and cotton planted to herbicide tolerant varieties for 1996-2004 and totals for the nine-year period. In 1996, the first year of commercial introduction, HT technology was used on 5.8 percent of the acres planted to the three major crops. The share planted to HT crops almost doubled in 1997, and then almost tripled in 1998. Growth has slowed since, reaching 51 percent of the acreage planted to the three crops in 2004.

The dominance of herbicide-tolerant soybeans as a share of total acres planted to HT varieties since 1996 is evident in Table 3. Over the first nine years of commercial

planting of HT varieties, HT soybeans have accounted for three-quarters of the total HT-acres planted, and 54 percent of total GE plantings, including both HT and *Bt* transgenic acres. This is why the impact of HT soybeans on herbicide use plays such a major role in determining the overall impact of GE crop technology on total pesticides use since 1996.

National acres planted by crop to *Bt* transgenic varieties of corn and cotton is presented in Table 4 for the period 1996-2004. A total of 182.6 million acres have been planted since 1996, with corn accounting for about 80 percent and cotton, 20 percent. Corn acres planted to *Bt* varieties actually fell in 2000 and 2001, and cotton acres planted declined from 2001 to 2002. But over the full nine-year period, the percent of total national corn plus cotton acres planted to *Bt* varieties increased from 3.1 percent to 34.1 percent.

As in the case with HT varieties, the rapid growth in adoption of *Bt* transgenic varieties occurred in the first four years of commercial use. In crop year 2004, the first corn varieties engineered to express the Cry 3Bb *Bt* toxin for control of corn rootworms were introduced. Table 4 does not include the estimated two to four million acres planted to these new varieties.

D. AVERAGE PESTICIDE USE ON GE AND CONVENTIONAL CROP ACRES

Despite longstanding public debate over the impact of GE crop technology on pesticide use, the USDA does not routinely collect nor report data comparing the average pounds of pesticides applied per acre on cropland planted to GE varieties compared to conventional varieties. Accordingly, indirect methods must be used to estimate pesticide use on GE versus conventional crop acres.

Calculations in this report of the impacts of GE varieties on average per acre pesticide use are based on publicly accessible National Agricultural Statistics Service (NASS) pesticide use data specific to a given crop, year, and pesticide. A three-step methodology is used.

First, the number of acres producing HT and *Bt* transgenic crops each year is calculated using USDA data on the total acres planted to corn, soybeans, and cotton by year, and the percent of acres planted to various GE crops, as shown in Tables 1 through 4. Three tables in the appendix present more detailed adoption data by State. There is widespread agreement on these estimates, although a survey carried out by the American Corn Growers Association in the early summer, 2004, suggests that the USDA estimate of adoption of *Bt* corn in 2004 may be marginally inflated.

Second, the average pounds of pesticides applied per acre on conventional (non-GE) acres are calculated for each year and GE technology, along with the average rate of application on acres planted to each GE trait. The rate applied to the GE portion of the crop is then compared to the rate applied to conventional acres, producing an estimate of the average difference in pesticide use between conventional and GE-planted acres. The differential is measured in pounds of herbicide or insecticide active ingredient per acre.

This approach rests on the assumption that an acre not planted to the GE trait would receive the same level of pesticide use as acres planted to non-GE varieties.

In the third and last step, the difference in pesticide pounds applied per acre for each GE technology for a given year is multiplied by the acres planted to the GE crop that year, producing an estimate of the increase or decrease in pesticide use. These differences are then added across the nine-year period, producing estimates of the total impact of HT and *Bt* transgenic varieties on herbicide and insecticide use, both by crop and by trait.

Estimating Average Application Rates by GE Technology

Annual USDA-NASS pesticide use surveys are the only publicly accessible, consistent time-series data on the volume of pesticides applied on corn, soybeans, and cotton. Even for these three major field crops, USDA does not collect pesticide use data every year. No cotton data was collected in 2002 and remarkably, given the intense public debate over herbicide use in HT soybeans, no soybean pesticide use data was collected in 2003. In both cases, pesticide use estimates in this report for the missing year were based on extrapolation of trends in recent years.

By state and at the national level for a variety of crops, NASS surveys record and report the percent of acres treated with a given pesticide, the average rate of application (for each distinct application), the average number of applications, the rate per crop year (average one-time rate multiplied by the number of applications), and the total pounds applied. Electronic copies of annual NASS survey results covering 1991 through 2003 are accessible at <http://usda.mannlib.cornell.edu/reports/nassr/other/pcu-bb/#field>.

In the case of herbicide tolerant crops, the pounds of herbicides applied per HT crop acre in a given year were estimated by adding together the glyphosate rate of application in that year as reported by NASS, and an estimate of the average pounds of other herbicides applied. The basis for the estimates of other herbicide use on HT acres for each crop is discussed in the following sections.

The pounds applied on non-GE acres were then calculated using a simple mathematical formula –

Herbicide Pounds Applied per Acre of Non-HT varieties of Crop_x =

[USDA Ave Rate All acres crop_x – (% acres HT varieties crop_x x Rate GE varieties crop_x)] divided by (% acres non-HT varieties crop_x)

This formula is based on the standard equation used to calculate a weighted average of two values – in this case, the average of the pounds of herbicides applied on HT acres and the pounds applied on conventional acres. These rates of application, weighted by their respective share of total acres planted, must equal the average pounds of herbicides applied on all crop acres as reported by NASS for a given year.

In the above equation, the average pounds of herbicides applied on all acres of a given crop (“USDA Ave Rate All acres crop_x”) are calculated from NASS survey data. USDA data are also available to calculate the share of crop acres planted to HT versus conventional varieties (data are reported in Table 2). NASS pesticide use data, coupled with information from herbicide manufacturers and universities, was used to estimate the average pounds of all herbicides applied on HT acres, leaving only one variable to calculate by solving the above equation. The impact of HT technology on herbicide use in a given year, by crop, is then calculated by subtracting the average rate applied to conventional acres from the average rate applied to HT acres. When this number is negative, HT technology reduced herbicide use; when it is positive, average herbicide use per acre increased.

Throughout this report, pesticide use estimates for 2004 are preliminary, since USDA will not release field crop pesticide use for 2004 until May 2005. Pesticide use estimates for 2004 are based on levels in 2003 and trends in recent years. For corn and cotton, the estimates for 2004 are conservative, in that they reflect a smaller percentage increase from 2003 to 2004 than the increase evident in USDA data from 2002 to 2003. The estimated increase in herbicide use on HT soybeans between 2003 and 2004 is also conservative. Three major factors drove up HT soybean herbicide use per acre in 2004 –

- Soybean producers had to contend with several tolerant and resistant weeds, some of which infested substantial acreage for the first time in 2004;
- Aggressive marketing by all major herbicide manufacturers of new combination products specifically formulated to augment weed control in RR soybeans. These new products contained two, and sometimes three, active ingredients; and
- Falling prices of herbicides containing glyphosate, and indeed most herbicides registered for use on soybeans, allowed farmers to increase applications without raising costs.

Pull quote – “There are increasing concerns that glyphosate-resistant common lambsquarter may occur in Wisconsin.”

Glyphosate Stewardship Program
Univ. of Wisconsin Extension, 2994

1. Herbicide Tolerant Corn

Farmer adoption of herbicide tolerant corn has progressed much more slowly than HT soybeans and cotton, in large part because growers have several other, comparably effective herbicide-based weed management alternatives. Farmers and university experts agree that managing weeds in corn in the mid-1990s was much simpler and more reliable – and less costly – than weed management in soybeans or cotton.

The average rate of herbicide application on HT corn acres was calculated as a weighted average between the rates in the two major HT corn weed management programs – the “Roundup Reliant” program and the “Residual Herbicide Applied” program. These are the two basic program options discussed in the Monsanto Roundup

Ready corn technical guide, and “Roundup Ready” HT technology accounts for virtually all HT corn acres. These program options are also discussed in the weed management field guides, bulletins, and reports issued by all midwestern land grant university weed management departments.

The rates of glyphosate applied in these programs are based on the average NASS rates per acre reported for each year. Weed management experts were consulted in determining that about 30 percent of corn HT areas are planted using the “Roundup Reliant” program and about 70 percent adhere to the “Residual Applied” program.

The “Roundup Reliant” program utilizes an average of two applications of glyphosate, while the “Residual Herbicide Applied” program depends on a single application. For both programs, the one-time rate of application of glyphosate reported by NASS was used in calculating the pounds of glyphosate applied.

Differences in average herbicide use on HT and conventional corn acres are calculated in Table 5. The first line of data in the table reports the NASS average rate for glyphosate per crop year. These rates take into account both the average rate per single application and the average number of applications per acre. The second line shows the average one-time application rate of glyphosate.

Note the substantial jump in the glyphosate rate per crop year from 2002 to 2003, and from 2003 to 2004. NASS reported that the average rate increased from 0.7 to 0.83 pounds per acre from 2002 to 2003, an increase of 18.6 percent. Average glyphosate use per crop year in 2004 was estimated at 0.9 pounds per acre, a 7.8 percent increase over 2003 use rates. This increase is less than half the jump reported by NASS between 2002 and 2003, and as previously noted, is likely conservative. The upward trend in per acre herbicide use on HT corn acres is driven by the same dominant factors noted above that are also increasing HT soybean herbicide use.

The difference in herbicide use on HT versus conventional corn acres shifted from a reduction of 0.8 pounds per acre in 1996 to an increase of 0.39 pounds in 2004. This shift from a significant reduction to a moderate increase in herbicide use is caused by a combination of two factors –

- Increased average herbicide use on HT acres; and
- Reductions in the pounds of herbicides applied on conventional corn acres, as a result of regulatory restrictions on high-dose herbicides including atrazine, the replacement of metolachlor with the lower-rate herbicide S-metolachlor, and the registration of a growing number of low- and very-low-dose corn herbicides.

The big change between 2001 and 2002 was brought about by the drop in the average pounds applied to non-HT acres from 2.25 pounds per acre to 1.87 pounds per acre. This came about because of the combination of regulatory restrictions on high-rate herbicides and the shift to low-dose herbicides. NASS reported that the rate of the most widely used corn herbicide atrazine fell from 1.18 in 2001 to 1.04 in 2002. The registration of S-metolachlor in 1997 allowed farmers to cut the rate of application of a

widely used, staple corn herbicide about 0.6 pounds per acre, without any sacrifice of weed control. This reduced-rate herbicide has decreased corn herbicide use on conventional corn acres by 10 to 12 million pounds annually since 1999.

Note that the big drop in average pounds applied per acre in 2000 is reflected in the reduction in the glyphosate rates that year, as well as the pounds of other herbicides applied on HT acreage.

Herbicide use on Roundup Ready (RR) corn acres is almost certainly going to increase further. Monsanto has recently reported another aggressive round of price cuts, coupled with enhanced promotional programs for farmers buying Monsanto seed and Monsanto brand herbicides. Throughout the late summer and fall, most major farm magazines have been running a Monsanto advertising campaign that promotes the RR corn system, featuring its compatibility with common tillage and planting systems and capacity to reduce costs. The “Roundup Ready Corn 2” program is composed of three steps –

“Spray [with Harness Xtra] for early weed control” prior to planting;
“Plant RR Corn 2”; and
“Spray Roundup Herbicide” during the growing season.”

Harness Xtra is a Monsanto herbicide mixture containing developed for RR corn that contains its proprietary herbicide acetochlor and atrazine. This product targets early season and residual grass control and is applied at a recommended rate of 1.8 to 2.3 quarts per acre, depending on soil type. Rates as high as 2.7 quarts are recommended in the event of heavy weed infestation. Assuming an average application rate of 2 quarts per acre, just modestly above the minimum label rate, an application of Harness Xtra, followed during the season with a single application of glyphosate, results in the following rates of herbicide application per acre –

- Acetochlor – 2.15 pounds
- Atrazine – 0.85 pounds
- Glyphosate – 0.7 pound
- Total program – 3.7 pounds.

Some fields of RR Corn 2 will require two applications of glyphosate, leading to a total of 4.4 pounds of herbicide applied per acre. Even if one application of glyphosate proves effective, this newly recommended Monsanto program requires substantially more herbicide per acre than the projections for 2004 under the “Residual Herbicide Applied” section in Table 5, where the total herbicide volume applied is estimated at 2.39 pounds per acre.

[Pull quote in this section – Monsanto’s newly recommended “Roundup Ready Corn 2” program requires 3.7 to 4.4 pounds of herbicide per acre, about twice the amount needed just a few years earlier.]

2. Herbicide Tolerant Soybeans

Table 6 presents average herbicide application rates per acre on conventional versus HT soybeans over the nine-year period. As in the case of HT corn, HT soybeans reduced herbicide use moderately in the first two years on commercial use. By the fourth year of use, herbicide use started to rise. By the seventh year of use, the average increase in per acre herbicide use equaled the decrease in applications in the first year of use. The biggest jump occurred between 2000 and 2001, the year glyphosate went off patent and herbicide prices were dramatically cut in a struggle among the leading herbicide manufacturers to increase or hold market share.

USDA data shows a clear upward trend in glyphosate and HT herbicide rates per acre since 2001. The 22 percent jump in glyphosate pounds applied per acre from 2001 to 2002 was caused by price reductions, the need to control more difficult sets of weeds, and the emergence of resistance and/or lessened sensitivity in many weed species that were once fully controlled by a single glyphosate application.

The pounds of all herbicides applied per acre of HT soybeans by year were estimated in Table 6 by adding to the USDA reported rate of application of glyphosate –

- An average of 0.15 pounds of other herbicides in 1996 and 1997;
- 0.22 pounds of other herbicides in 1998-2001;
- 0.25 pounds in 2002-2003; and
- 0.3 pounds in 2004.

NASS did not collect soybean pesticide use data in 2003, so rates in 2003 and 2004 per projected from recent trends and weed management updates on land grant university websites. Crop year 2003 was an extremely challenging one for soybean weed management. Erratic weather in the spring delayed herbicide applications in some areas, allowing hard-to-control weeds to reach a size requiring higher rates of glyphosate application and/or treatment with additional herbicides. Untimely spring rains washed some applications of glyphosate off weeds before uptake, requiring retreatment. Glyphosate resistant marestail emerged as a serious problem in a handful of states. In 2004, the extent and severity of weed control failures linked to resistant or tolerant weeds required a significant increase in herbicide use in many regions and accounted for most of the increase in per acre herbicide use projected between 2003 and 2004.

Picutre – gly resistat marestial from the Purdue report, “Figure 2”

Special Tabulation in 1998 Provides Solid Data Point

A series of special tabulations of herbicide use data on HT and conventional acres were carried out by the ERS at the request of Benbrook Consulting Services. The ERS divided the sample points in the 1998 Agricultural Resources Management Survey (ARMS) into four categories of soybean acres:

- Conventional varieties, no glyphosate applied;

- Conventional varieties, glyphosate applied (mostly on no-till acreage);
- Roundup Ready varieties; and
- Other HT varieties.

For 1998 ERS reported both the percent of total soybean acreage by category, as well as the average number of herbicides and pounds of herbicides applied in each category. This information was used to calculate total herbicide use per acre on conventional and HT soybeans in 1998, using a simple weighted average formula. The rates and percents of acres planted to conventional varieties treated and not treated with glyphosate were used to calculate the overall conventional-acres rate of 1.13 pounds per acre. (Conventional acres treated with glyphosate were planted using either no-tillage or conservation tillage systems in which the glyphosate is applied before soybean seeds germinate).

The same information was used to calculate the average rate of all herbicides applied on HT acres, which was 1.2 pounds per acre. These results are reported in Table 7 and show that the average acre of HT soybeans in 1998 was treated with 0.07 pounds more herbicide than conventional acres. This is the most accurate estimate of this difference that can be made drawing on available USDA data on actual herbicide use. The difference reflects total herbicide use per acre reported by farmers on fields planted to HT versus conventional varieties. This solid estimate of the difference was used to calibrate the estimates in Table 6, which also reports a difference of 0.07 pounds per acre in 1998 between the pounds of herbicides applied on HT versus conventional acres.

The average rate for all herbicides applied to soybeans in 1998 was 1.08 pounds according to NASS data, as shown in the 1998 column in Table 6. On HT acres, an average of 0.9 pounds of glyphosate was applied, again according to NASS survey results. An estimated 0.22 pounds of other herbicides were applied on HT acres. Total herbicide use on HT acres was 1.12 pounds. This estimate, along with NASS-reported total herbicide use of 1.08 pounds, was then used to calculate the average rate on conventional acres using the weighted average formula. This calculated rate was 1.05 in 1998.

The estimate of 1.05 pounds of all herbicides applied on non-HT acres and 1.12 on HT acres in Table 6 corresponds to the correct differential of 0.07 pounds per acre, as reported in the special ERS tabulation of actual use data in Table 7.

3. Herbicide Tolerant Cotton

Weed management in cotton has always required more herbicide per acre than soybeans. This is because cotton fields are planted in somewhat wider rows and do not form as dense of a closed canopy of foliage as soybeans. More weeds germinate and grow in cotton fields compared to soybeans because more sunlight reaches the ground. In addition, the growing season for a cotton crop is longer, which gives weeds more time to get established and requires active management of weeds over a longer period of time. In the first few years of commercial use, many HT soybean farmers got through a season

with very clean fields following just one application of glyphosate; cotton farmers planting HT varieties were never able to replicate this level of performance and always needed to apply additional herbicides or multiple applications of glyphosate or bromoxynil, the other herbicide used in conjunction with HT cotton varieties.

The difference in herbicide application rates on HT cotton and conventional varieties shifted incrementally over time much like in the case of HT corn and soybeans, as shown in Table 8. In the first two years of commercial use, each acre planted to HT cotton reduced herbicide use by about one-third pound. Efficacy slipped in years three and four such that there was essentially no difference in total herbicide use on HT and conventional acres.

By year five, weed shifts, tolerance, and resistance had pushed total herbicide use on HT acres to a level 0.23 pounds above total herbicide use on conventional acres. The upward trend has continued, reaching a differential of 1.01 pounds in 2003, a very difficult year for weed management in cotton country. Substantial weed control failures in 2003 in parts of the cotton belt, coupled with the rapid spread of glyphosate-resistant marestial, made weed management even more difficult in 2004, triggering an estimated 10 percent increase in the average pounds of herbicides applied her acre.

NASS reported a large jump in glyphosate use per acre of cotton between 2001 and 2003 – 1.12 pounds to 1.38 pounds per acre. (Recall that NASS did not collect cotton pesticide use data in 2002). Table 8 assumes that the total increase of 0.26 pounds was evenly divided between the two subsequent production seasons. The average acre of HT cotton was treated with 0.8 to 1.1 pounds of herbicides other than glyphosate from 1996 through 2004, with levels tracking general trends in total herbicide use.

The reduction in average pounds applied on conventional acres accelerated between 1999 and 2000, reflected the registration and wider use of low-dose herbicides and herbicide mixtures. Heavier weed pressure, triggered in part by weed control failures on some crop acres in 2003, accounts for the increase in pounds applied in 2004, despite the availability of several low-dose products.

4. *Bt* Transgenic Corn

Calculating the impact of *Bt* corn on insecticide use is complicated by several factors. For decades, about 8 to 12 percent of the corn acres planted nationally have been treated for control of European corn borers (ECB) and/or Southwestern corn borers (SWCB) -- the insects targeted by *Bt* corn. In its third year of commercial use in 1998, *Bt* corn was planted on 19.1 percent of national corn acres – about twice the acreage ever sprayed to control the ECB or SWCB. Clearly, a significant portion of the acres planted to *Bt* corn varieties in 1998 and since would not have been sprayed if the farmers had continued to plant conventional varieties. Accordingly, estimates have to be made of the portion of the acreage planted to *Bt* corn each year that would have likely been sprayed with insecticides for management of ECBs and/or SWCBs.

The third line of data from the bottom of Table 9 is labeled “Percent Acres Planted to *Bt* Previously Treated with Insecticide.” It presents annual estimates of the share of *Bt* corn acres that would have been sprayed and starts out very high – an estimated 90 percent of the 1.1 million acres of *Bt* corn in 1996 would likely have been sprayed. As the acres planted to *Bt* corn increases, the percentage that was likely sprayed with insecticides declines. Over the period 1997 through 2004, the percent of *Bt* corn acres planted that would have been sprayed is estimated to vary between 26 and 33 percent. In 2004 about one-third of national corn acres were planted to *Bt* corn. An estimated 27 percent of these acres had previously been treated with insecticides for ECB and/or SWCB management. Accordingly, *Bt* corn reduced insecticide use on about 7 million acres.

The introduction of *Bt* corn varieties in the mid-1990s heightened research and grower focus on the damage caused by ECBs and SWCBs. As a result of better documentation of the losses caused by these insects, farmers have managed them more aggressively in recent years. This is evident in Table 9, which reports that the combined number of acres planted to *Bt* corn, plus acres producing conventional corn that were sprayed with insecticides for ECB/SWCB control rose appreciably above historical levels. In 2003, for example, 7 million acres were planted to *Bt* corn and 8.8 million acres were sprayed with insecticides for ECBs and SWCBs, for a total acreage under insect pest management of 15.8 million acres. This estimate of the acres treated for ECBs/SWCBs reflects about a 50 percent increase over historical levels. Some land grant entomologists are urging farmers to rethink their decision to automatically plant *Bt* corn for ECB/SWCB in those parts of the Cornbelt where population levels have been low in recent years. Strong evidence suggests that corn growers are now overtreating for ECBs/SWCBs in some major growing areas, resulting in unnecessary expenditures, needless impacts on nontarget species like Monarch butterflies, and increasing the risk of resistance.

The method used to estimate the average pounds of insecticides applied on corn acres for management of ECB/SWCB is straightforward. USDA data and university pest management specialists indicate that eight insecticides are applied for the management of the ECB/SWCB. Of these, three are generally applied largely or solely for control of the ECB/SWCB:

- Lambda-cyhalothrin;
- Cyfluthrin; and
- Permethrin.

Five other insecticides are applied for control of multiple corn insect pests, including the ECB/SWCB, corn rootworms, cutworms, armyworms, and aphids. These insecticides, and the share of their annual use that targets the ECB/SWCB, are:

- Chlorpyrifos (10 percent);
- Bifenthrin (50 percent);
- Esfenvalerate (75 percent);
- Dimethoate (75 percent); and
- Methyl parathion (25 percent).

Corn insecticide use data from the USDA were used to calculate the average pounds per acre of these eight insecticides that were applied to corn acres by year. The estimates are weighted by each insecticide's share of the total pounds of the eight insecticides that were applied. The results are reported in the "Conventional Corn – Weighted Average Rate per Acre Treated" line in Table 9 and show a steady decline in the average pounds of insecticides applied per acre for control of the ECB/SWCB from 0.18 pounds in 1996 to 0.06 in 2003 and 2004. The shift in acres treated toward very low-dose synthetic pyrethroid insecticides, especially cyfluthrin, accounts for the significant reduction between 2001 and 2003. Cyfluthrin is applied at only 0.006 pounds per acre and has been the market leader since 2001.

Because *Bt* corn works so well in controlling ECBs/SWCBs, very few farmers planting *Bt* corn had to also treat their fields with insecticides for control of the ECB/SWCB. For this reason, projected ECB/SWCB insecticide applications on *Bt* corn acres are zero. The estimates of insecticide use on *Bt* corn acres does not include the amount of *Bt* toxin manufactured by the corn plants within their cells. It is generally correct to state that no insecticides are sprayed on virtually all acres of *Bt* corn, but inaccurate to claim that no insecticide was used on acres planted to *Bt* corn, given that the plants produced the *Bt* toxin internally.

The last step in estimating the reduction in insecticide use associated with the planting of *Bt* corn is carried out at the bottom of Table 9. The percent of acres planted to *Bt* corn that would previously have been treated with insecticide is multiplied by the average rate of application of insecticides to treat these insects. The amount of insecticide saved per acre of *Bt* corn in 1996 was 0.16 pounds of active ingredient. As more acres of *Bt* corn were planted, insecticide use was reduced on a smaller share of these *Bt* acres, leading to a lower average reduction in insecticide use across all acres planted to *Bt*. In recent years, the reduction has been only 0.02 pounds per acre, reflecting the fact that conventional corn acres treated for ECBs/SWCBs were sprayed on average with just 0.06 pounds of insecticide and the estimate that insecticide use was reduced on about 30 percent of the acres planted to *Bt* corn (30 percent of 0.06 pounds is 0.02 pounds).

Figure X summarizes these findings and reports the average rate of insecticide applications to conventional corn for control of the ECB/SWCB by year, as well as the average reductions in insecticide use per acre planted to *Bt* corn.

Figure X. Trends in Insecticide Applications to Manage the European Corn Borer and Southwestern Corn Borer and the Reduction in Insecticide Use on *Bt* Corn Acres

5. *Bt* Transgenic Cotton

Unlike the case with *Bt* corn, nearly 100 percent of the acres planted to *Bt* cotton were previously sprayed for control of the target pests, the Budworm/Bollworm complex.

Accordingly, the method used to estimate the difference in insecticide use on acres planted to *Bt* and conventional cotton varieties is simpler than in the case of *Bt* corn.

Fourteen insecticides are applied largely for the management of the Budworm/bollworm insect complex, as shown in Table 10. Based on the total pounds applied across these 14 insecticides and the acres of conventional cotton planted by year, average insecticide application rates on non-*Bt* cotton acres were calculated and appear in Table 10 in the row “Budworm/Bollworm Conventional Rate.” As in the case with corn, the rates of insecticides applied on conventional acreage declines somewhat over the nine-year period, reflecting adoption of lower-rate products.

While *Bt* cotton is highly effective in many areas, it does not eliminate insecticide applications targeting the Budworm/Bollworm complex. Accordingly, it was assumed that the average acre of *Bt* cotton was treated with 0.1 pound of insecticides. The estimated average 0.1 pound of insecticides applied per acre planted to *Bt* cotton also takes into account of the pounds of *Bt* endotoxin produced within the cells of *Bt* cotton plants. Accordingly, the reduction in insecticide pounds applied per acre planted to *Bt* cotton ranges from 0.46 pounds in 1996 to 0.16 pounds in 2001.

E. IMPACTS OF GE CROP TECHNOLOGY ON PESTICIDE USE, 1996-2004

Three crops have accounted for nearly all acres of crops planted to genetically engineered (GE) varieties in the U.S. since 1996. About 487 million acres have been planted to herbicide tolerant (HT) corn, soybeans and cotton, and another 183 million acres to *Bt* transgenic corn and cotton. Accordingly, HT crops have accounted for 73 percent of total GE crop plantings and *Bt* transgenic crops were grown on the other 27 percent. HT soybeans are by far the dominant GE crop, accounting for three-quarters of all acres planted to HT varieties and over half all GE crop acres since 1996. Chart X summarizes these findings.

Chart X. [Pie chart with total GE acres broken into HT and Bt blocks; and the blocks broken into the three/two crops, if you can do it]

1. Major Findings Across Three Major Crops

Table 11 integrates all the estimates of average pesticide use rates per acre on GE-planted acres in contrast to acres planted to conventional. For each crop and GE trait, the rates of pesticide use and the average differences per acre in pounds applied between GE and conventional acres are shown for 1996-2004.

The impact of GE crops on total pounds of pesticides applied across the three crops and for both HT and *Bt* traits are reported in Table 12. The numbers in Table 12 are calculated by multiplying the average difference in pesticide use per acre of crop planted to a GE trait by the acres planted to that GE trait each year. The last four rows of

the table add together the impact of GE technology on total herbicide, insecticide, and herbicide plus insecticide use across the three crops.

Across all traits, GE crops reduced pesticide use 20.6 million pounds from 1996 through 1998, but from 1999 through 2004, pesticide use rose 143 million pounds, for a net increase of 122 million pounds over the full nine-year period. Chart X contrasts the change in pesticide use in the 1996-1998 compared to 1999-2004.

Chart X. Changes in Pesticide Use in the First Three Years of Commercialization Compared to the Last Five Years

[three bars; left vertical axis is “Change in Pesticide Use”; first bar is 1996-1998 and has a negative sign in front of the number placed atop the bar; second one is increase 99-2004; third is 1996-2004.]

Herbicide tolerant corn reduced the total pounds of herbicides applied from 1996 through 2001, but has led to increases each year since. Moreover, HT corn is requiring more and more herbicide each year compared to acres planted to conventional varieties, a negative trend driven by shifts in weed communities, resistance, and the sizable drop in the price of glyphosate herbicides. Over the nine-year period, HT corn reduced total herbicide use an estimated 6.3 million pounds, but in 2004, 5.6 million more pounds of herbicides were applied because of the planting of HT corn.

Bt corn reduced insecticide use each year, but only marginally given the very low rate of insecticides applied on conventional corn acres for control of the ECB/SWCB. Over the nine-year period *Bt* corn reduced insecticide use by about 4.5 million pounds. GE traits in corn have therefore reduced pesticide use by about 10.8 million pounds over the last nine years, less than a 1 percent reduction in total corn herbicide plus insecticide pounds applied.

Herbicide tolerant soybeans reduced the total pounds of herbicides applied for the first two years of commercial use, but have triggered the need for increased use since. Over the nine-year period, 117 million pounds more herbicide has been applied because of the planting of HT soybeans. This large increase reflects a 15.8 percent increase in soybean herbicide use and reflects the slipping efficacy of the Roundup Ready system, the emergence of tolerant and resistance weeds, and the falling price of soybean herbicides.

HT cotton reduced herbicide use in three of the first four years of commercial use but thereafter required steadily more herbicides to keep up with weed shifts and resistant/tolerant weeds. Over the nine-year period, HT cotton required 26.8 million pounds more herbicides than if HT acres had been planted to conventional varieties. *Bt* cotton, on the other hand, substantially reduced insecticide use over its nine years of commercial use, resulting in a total decrease of 15.6 million pounds. GE traits led to an increase of 15.7 million pounds in combined herbicide plus insecticide use from 1996-2004.

Given that the insecticide use avoided by the planting of *Bt* cotton involved some of the most toxic pesticides currently registered for use, and the relatively benign environmental profile of glyphosate herbicides, GE traits clearly reduced the adverse impacts of cotton pest management, despite the fact that they did not reduce the volume of pesticides applied.

Across the three crops, HT varieties increased herbicide use by 138 million pounds over the nine-year period, or by about 5 percent. The two *Bt* transgenic crops reduced insecticide use by 15.6 million pounds, or by about 4.7 percent. All GE crops planted since 1996 have increased corn, soybean, and cotton pesticide use by 122.4 million pounds, or about 4 percent. Chart 5 places these findings into perspective. It shows by year the percentage change in total pesticide use on corn, soybeans and cotton brought about by the adoption of HT and *Bt* crops.

Chart X. Annual Percent Change in Pesticide Use Brought About by Herbicide Tolerant and *Bt* Transgenic Corn, Soybeans, and Cotton

[data from last line, table 12, 1996-2004. Have vertical axis go above zero and below zero to show difference between neg and pos percent change]

2. Conclusions and Future Prospects

While the discovery and adoption of GE crop technology has changed American agriculture in many ways, reducing overall pesticide use is not among them. *Bt* transgenic crops have reduced overall insecticide use, but HT crops have increased it by a far greater margin.

Moreover, the performance of HT crops appears to be slipping. The average acre planted to glyphosate tolerant crops is requiring more and more help from other herbicides, a trend with serious environmental and economic implications. Resistance to glyphosate has emerged as a very serious concern across most of the intensively farmed regions of the U.S. The number of resistant weeds, and rate of spread is not surprising given the degree of selection pressure imposed on weed populations by farmers applying glyphosate herbicides multiple times per year, and sometimes year in and year out on the same field.

Resistant weeds typically emerge first on just a few isolated fields, but their pollen, genes, and seeds can travel widely and spread quickly, especially if glyphosate continues to be relied on as heavily as it has been in recent years. This is why both universities and some herbicide manufacturers are calling for more aggressive, and prevention-oriented management of resistance to glyphosate. In the case of the weed marestial, the recent focus on resistance management has come too late.

No substantial change in the intensity of glyphosate use in the U.S. is expected in the foreseeable future, given the continued popularity of HT crops dependent on

glyphosate, the limited supply of non-HT seed in some popular varieties, and the increasingly aggressive promotions offered to farmers relying exclusively on Roundup Ready technology. As a result, marestial will almost certainly be the first of several glyphosate resistant weeds that emerge and spread, triggering the need for additional herbicide applications and eroding the cost advantage and popularity of HT technology.

The future of *Bt* transgenic crops is brighter, especially in the case of *Bt* cotton. Several university and USDA researchers are closely monitoring efficacy in *Bt* cotton, which appears to have changed little over the last nine years. The attention focused on resistance management, and the issuance of mandatory resistance management plans, has proven effective thus far in delaying the emergence of resistance. Indeed, some experts now think that the emphasis on resistance management in *Bt* cotton can be relaxed. History suggests that lessened diligence in cotton insect resistance management efforts would be premature, given that it has taken 10-15 years for cotton insects to develop resistance to each new type of insecticide applied to control them. This cycle began with the organochlorines in the 1960s and 1970s, and then repeated itself with the carbamates in the 1970s and 1980s and the synthetic pyrethroids in the 1980s and 1990s. Prudence dictates waiting until about 2010 before determining whether contemporary resistance management plans are indeed working and might possibly be simplified.

Bt corn for control of ECBs and SWCBs remains highly effective but is also almost certainly overused. Many farmers are planting these varieties as an insurance policy against potentially damaging insect populations. In 2004, Monsanto introduced its new Cry 3Bb *Bt* corn for rootworm management and by 2005, several corn varieties will express both the *Bt* toxin targeted toward the ECB/SWCB and the new toxin designed to manage corn rootworms.

There has been virtually no field research or regulatory review of the ecological and food safety implications when widely planted *Bt* corn varieties are simultaneously expressing dual *Bt* genes. Current USDA and EPA approvals are based on the assumption that the two *Bt* transgenes in corn plants will operate exactly as they do in varieties engineered to express a single *Bt* gene, and that the impacts of the dual transgenes will not in any way be additive or decrease the stability of gene expression. These are significant and questionable assumptions that if incorrect, could lead to major, unintended consequences. For this reason, these assumptions should be subjected to empirical study before widespread planting of dual-*Bt* varieties is authorized.