Resources & Environment

Monsanto

Genetically Engineered Crops: Has Adoption Reduced Pesticide Use?

Development of new crop varieties through genetic engineering offers a broad spectrum of potential benefits, including reduced production costs, enhanced yields, and enhanced nutritional or other characteristics that add to value. Among the first developments on the market were changes in the genetic makeup of common field crops that made them tolerant to commonly used glyphosate herbicides, or that incorporated genes of the natural pesticide *Bacillus thuringiensis* (Bt), so that plants produce a protein toxic to specific insect pests.

These varieties appealed to producers because they promised to simplify pest management and reduce pesticide use, while helping to control costs, enhance effectiveness of pesticides (both herbicides and insecticides), and increase flexibility in field operations. Evidence of that appeal lies in the rapid adoption of genetically engineered crops, beginning with very little U.S. acreage in 1996 and reaching 41 percent of major crop acreage in 2000, down from 49 percent in 1999.

The potential to reduce pesticide use through genetic engineering, or biotechnology, could also appeal to consumers. A Farm Bureau/Phillip Morris poll of farmers and consumers in August 1999, for example, indicates that 73 percent of consumers were willing to accept genetic engineering as a means of reducing chemical pesticides used in food production. The poll also found that 68 percent considered farm chemicals entering ground and surface water to be a major problem.

The question remains: does adopting genetically engineered (GE) crops for pest management reduce use of chemical pesticides? As with most simple questions, the answer is far from simple.

Estimating Effects On Pesticide Use

Data exist on pesticide use by producers who did and did not adopt genetically engineered crops. But characteristics that affect the adoption decision may influence pesticide use decisions as well, making simple comparisons suspect. In addition, the changing mix of pesticides that accompanies adoption complicates the analysis, because characteristics like toxicity and persistence in the environment vary across pesticides.

To offer several perspectives on estimating changes in pesticide use associated with adoption of GE crops, this analysis uses three statistical methods.

- *Same-year differences.* Compares mean pesticide use between adopters and nonadopters within 1997 and within 1998 for a given technology, crop, and region, and applies that average to total acres producing each crop in each year.
- *Year-to-year differences.* Estimates aggregate differences in pesticide use between 1997 and 1998, based on increased adoption of GE crops between those 2 years and average total pesticide use by both adopters and nonadopters.
- *Regression analysis.* Estimates differences in pesticide use between 1997 and 1998, with an econometric model controlling for factors other than GE crop adoption that may affect pesticide use.

Data for the study are from the national Agricultural Resource Management Study (ARMS) for 1996-98, conducted by USDA's National Agricultural Statistics Service and Economic Research Service. The dataset includes information on adoption of GE varieties of corn, soybeans, and cotton, as well as number of applications and amounts of specific conventional pesticide applied. Only statistically significant differences in pesticide use were included in the estimates of change, so results are conservative. For insecticides, only those used to control the target pests of GE crops—i.e., those that could substitute for the Bt trait—were analyzed.

Same-year differences between average pesticide use of adopters and nonadopters revealed that adopters of GE corn, soybeans, and cotton combined used 7.6 million fewer acre-treatments (2.5 percent) of pesticides than nonadopters in 1997. (An acre-treatment is the number of acres treated multiplied by the number of pesticide treatments.) The difference rose to nearly 17 million fewer acre-treatments (4.4 percent) by adopters in 1998.

In 1998, adopters of herbicide-tolerant soybeans accounted for the largest share

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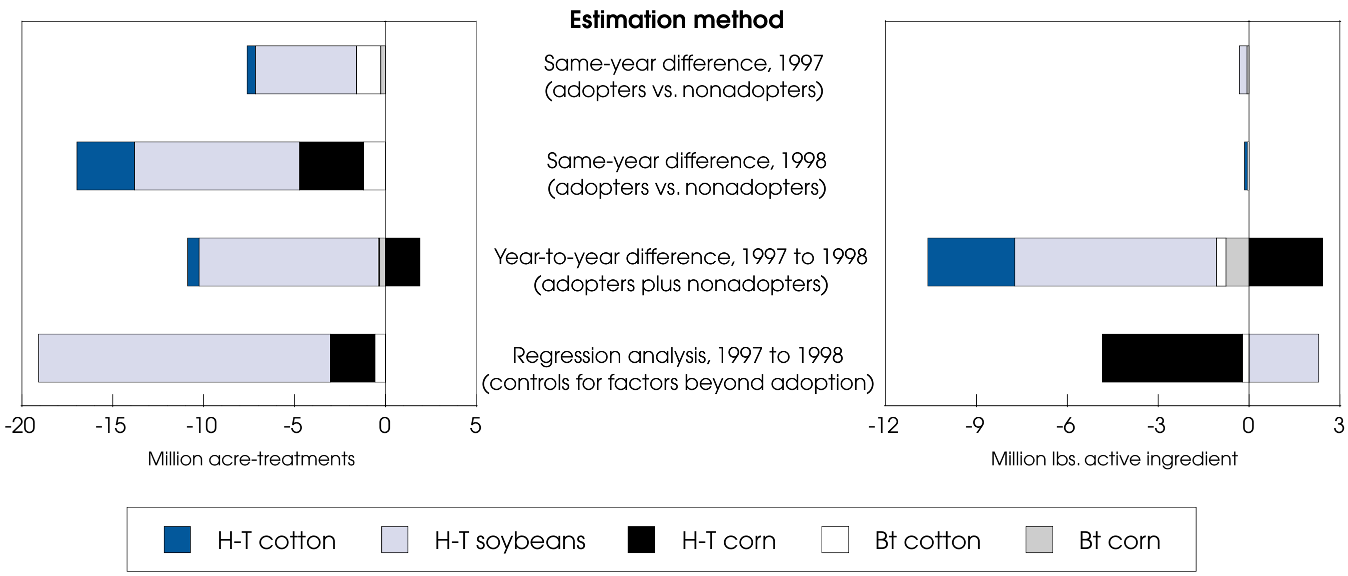
Reduction in Pesticide Use Accompanies Adoption of Genetically Engineered Crops



H-T = Herbicide-tolerant. Regression analysis controls for factors in pesticide use (acre-treatments and volume) beyond adoption of genetically engineered crops.
Source: Agricultural Resource Management Study, 1997 and 1998.

Economic Research Service, USDA

of the difference in acre-treatments (54 percent), with most of the reduction occurring in the Heartland region. Seven percent of the difference in acre-treatments for target pests occurred with adoption of Bt cotton, with most of the reduction in the Southern Seaboard.

In terms of active ingredients applied, however, adopters used only 331,000 pounds fewer than nonadopters (less than 0.1 percent of total pounds applied) in 1997. The difference narrowed to 153,000 fewer pounds in 1998. Reductions in active ingredients applied in 1997 were related to Bt cotton and herbicide-tolerant soybeans in the Southern Seaboard, while in 1998 herbicide-tolerant cotton and Bt corn accounted for most of the decreases nationally.

Year-to-year differences in total pesticide use between 1997 and 1998, adjusted for change in acres planted but including both adopters and nonadopters, amounted to 9 million fewer pesticide acre-treatments (a 2.9-percent reduction). Although GE adoption leads to less pesticide use, acre-treatments by GE adopters as a group increased by 49 million between 1997 and 1998, while acre-treatments by the shrinking number of nonadopters dropped by 58 million. This resulted in 8.2 million fewer pounds of active ingredients applied (3.5 percent)—the growing number of GE adopters used 39.3 million more pounds in 1998 than in 1997, but the declining number of nonadopters used 47.5 million fewer pounds.

Most of the decrease was in soybeans in the Heartland region, and in cotton. For corn, acre-treatments and pounds of active ingredient increased because GE adopters used 13.6 million more acre-treatments, while nonadopters decreased acre-treatments by only 11.8 million. The increasing number of producers who planted herbicide-tolerant corn used 17.5 million more pounds of active ingredients as they switched from other herbicides to glyphosate, but the fewer nonadopters reduced pesticide use by only 15.1 million pounds.

Year-to-year changes in total pesticide use result from sometimes dramatic increases in GE acreage. These increases lead to increases in total pesticide use by adopters, despite lower average per-acre rates. Corresponding decreases in nonadopter acreage lead to decreases in total pesticide use by nonadopters, but, except for corn, GE adopter increases are less than nonadopter decreases, resulting in a net decline in total pesticide use.

These comparisons do not account for year-to-year changes in weather conditions, pest pressures, and other factors that may affect pesticide use, so it is inappropriate to attribute the results solely to adoption of GE crops. Still, the overall downward trend in pesticide application rates on major U.S. crops from 1996 to 1998 appears to confirm the pesticide-reducing effect of GE crops.

For example, as adoption of herbicide-tolerant soybean varieties increased from 7 to 45 percent, the average annual rate of glyphosate application increased from 0.17 pounds per acre in 1996 to 0.43 pounds per acre in 1998, while all other herbicides combined dropped from about

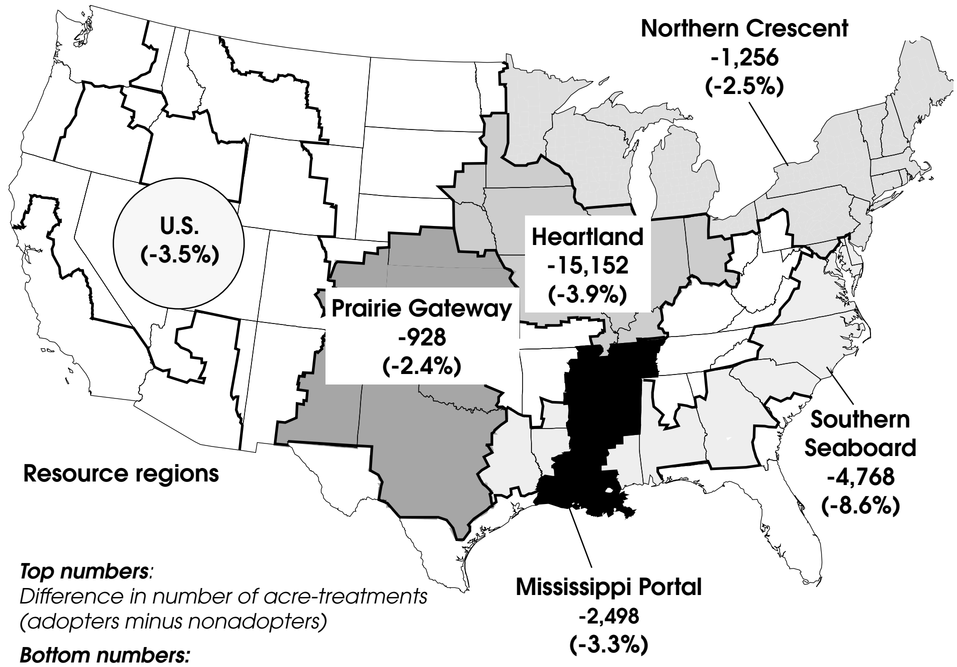
1 pound per acre to 0.57 pounds per acre. That translates into a decline of nearly 10 percent in the overall rate of herbicide use on soybeans during the period.

The *regression analysis approach* controlled for differences between adopters and nonadopters, allowing estimation of changes in pesticide use associated with increases in GE adoption between 1997 and 1998. Regression models are usually used to estimate small adjustments from small changes in conditions. Normally, changes in use of a technology would be small over a single year. However, between 1997 and 1998, spectacular growth in genetically engineered crop use led to adoption rate increases of 160 percent for herbicide-tolerant soybeans, 150 percent for herbicide-tolerant cotton, 12 percent for Bt cotton, and 43 percent for herbicide-tolerant corn. These large changes may be beyond the model's predictive scope.

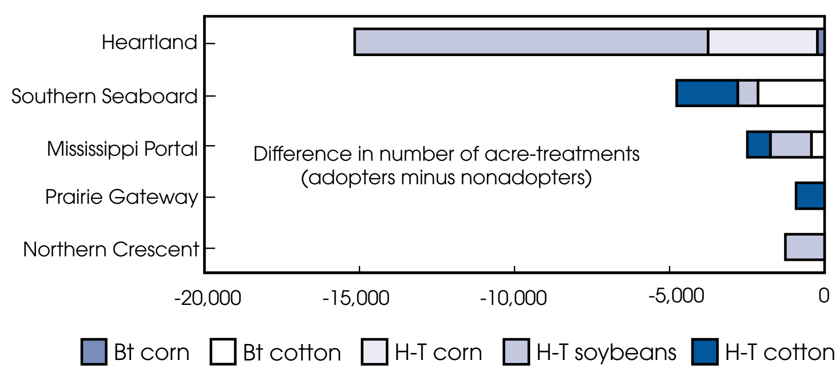
The analysis estimated that pesticide reductions related to increased GE adoption between 1997 and 1998 were 19.1 million acre-treatments (6.2 percent of total 1997 treatments), excluding Bt corn. These estimates reflect reductions in other insecticides used on cotton, acetamide herbicides used on corn, other synthetic herbicides used on soybeans, and offsetting increases in glyphosate herbicides used on soybeans

Assuming application rates of each active ingredient (pounds per acre-treatment) are the same for adopters and nonadopters, changes in the number of acre-treatments would imply proportional changes in pounds of active ingredients used. However, since average application rates vary across pesticide active ingredients, the net effect of substituting one for another may be an increase or a decrease in total pounds used. Thus, changing the mix of products used while decreasing acre-treatments may actually increase total pounds of active ingredients applied. Estimating the change in total pounds of active ingredients under the assumption of average application rates for each active ingredient indicates that total pesticide use on corn, soybeans, and cotton decreased 2.5 million pounds (1 percent) in 1998 compared with 1997.

Adopters of Genetically Engineered Crops Used Fewer Acre-Treatments of Pesticides Than Nonadopters



Top numbers:
Difference in number of acre-treatments (adopters minus nonadopters)
Bottom numbers:
Percent difference in regional acre-treatments (adopters minus nonadopters)



H-T = Herbicide-tolerant.
Difference in acre-treatments = Average of same-year differences in 1997 and 1998 between adopters and nonadopters.
Source: Agricultural Resource Management Study, 1997-98

Economic Research Service, USDA

Using average application rates gives conservative results. For example, using average application rates, the net effect of adopting herbicide-tolerant soybeans is a reduction in acre-treatments but a slight increase in pesticide use (pounds of active ingredients). However, direct econometric estimation shows a 1.76-million-pound reduction in herbicide use associated with increased adoption of herbicide-tolerant soybeans in 1998 relative to 1997, the net result of a 7.2-million-pound decrease from use of "other" herbicides and a 5.44-million-pound increase from use of glyphosate. When producers adopt GE crops, they shift the mix of pesticides they use and can use them at lower-than-average application rates. Thus, the actual reduction in pounds of active ingredients may be larger than that estimated by multiplying average rates by the reduction in acre-treatments.

Changing Pesticide Use: Impact Also Matters

Changes in pesticide acre-treatments resulting from the adoption decision range from -6.8 million acre-treatments to -19 million across the three estimation methods. Reductions in pounds of active ingredients vary more widely, from a net drop of just 0.3 million pounds in 1997 (using the same-year method to compare adopters and nonadopters) to a net 8.2-million-pound decrease (using the year-to-year method to compare changes in total pesticide use between 1997 and 1998). Because the results include only statistically significant differences in pesticide use by adopters and nonadopters, many relatively small differences in particular regions were not included, thus underestimating overall differences.

Assessing the impact of the herbicide-tolerance trait (which enables use of glyphosate herbicides) requires more than simply calculating whether more or less pesticide will be used. Adoption of this technology changes the mix of pesticides used in the cropping system, as well as the amounts used. In addition, effectiveness of the insect-resistant trait is limited—i.e., Bt-enhanced seed only targets certain pests—and some amount of conventional pesticide will still be used to control those not affected by the Bt toxin.

When pesticide mixes are changing, comparing the total *number* of acre-treatments or *pounds* of active ingredients of different pesticide compounds is like adding the proverbial apples and oranges. Measuring pesticide use in pounds of active ingredient implicitly assumes that a pound of any two ingredients has equal impact on human health and/or the environment. However, the more than 350 active ingredients in use in pesticides over the last 40 years vary widely in toxicity per unit of weight and in persistence in the environment. Scaling (weighting) pounds of pesticides applied by measures of their “toxicity/persistence” characteristics can provide an indication or index of pesticide impact or potential risk.

Regression Model Controls for Differences Between Adopters & Nonadopters

Comparison of means is sometimes used to analyze results from experiments in which factors other than the item of interest are “controlled” by making them as similar as possible. For example, to compare mean yield or pesticide use for two groups of soybean plots—one group that receives a “treatment” such as genetically engineered crops, and another that does not—the groups would ideally be equal in soil type, rainfall, sunlight, and all other respects. An alternative to a controlled experiment would be randomly selecting subjects that receive treatment and those that don’t.

In “uncontrolled experiments” such as the analysis which compares means from observations in farm survey data, interpretation of the results requires caution. Conditions other than the “treatment” are not equal in farm surveys. Factors that affect estimation results but cannot be controlled may include, for example, irrigation, weather, soils, nutrient and pest management practices, other cropping practices, operator characteristics, and pest pressures. Therefore, estimated differences cannot necessarily be attributed solely to use of the “treatment,” i.e., genetic engineering technology.

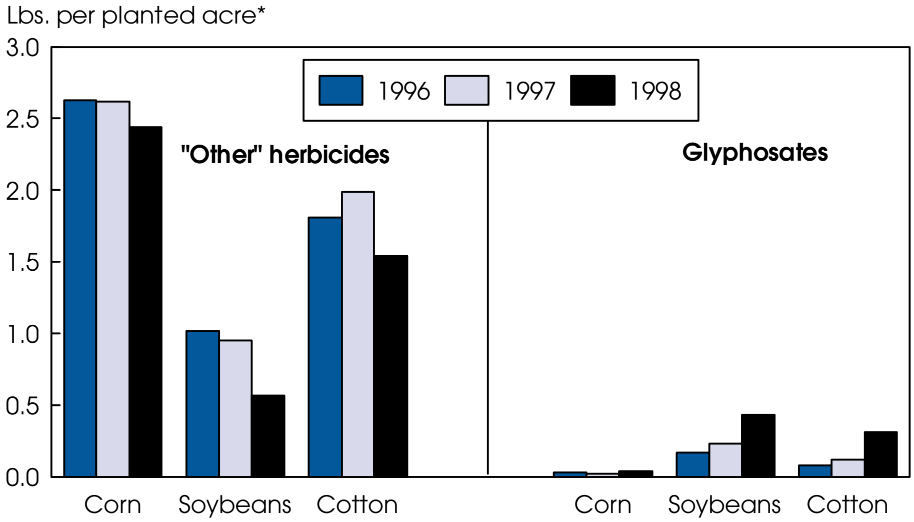
Moreover, farmers are not assigned randomly to the two groups (adopters and nonadopters), but make the adoption choices themselves. Therefore, adopters and nonadopters may be systematically different, and these differences may manifest themselves in farm performance that could be confounded with differences due purely to adoption. This situation, called self-selection, would bias the statistical results unless it is corrected.

The impacts of adopting genetically engineered (GE) crops are assessed by using an econometric model that statistically controls for other factors that affect pesticide use. Variables (factors) controlled for include output and input prices, infestation levels, farm size, and management practices such as rotation and tillage.

In addition, the econometric model corrects for self-selection to prevent biasing the results, and takes into consideration that farmers’ adoption and pesticide use decisions may be simultaneous, due to unmeasured variables correlated with both adoption and pesticide demand, such as the size of the pest population, pest resistance, farm location, and grower perceptions. Finally, the model ensures that pesticide demand functions (mathematical representations of pesticide use) are consistent with farmers’ optimization (e.g., profit-maximizing) behavior.

A two-stage model was developed to account for simultaneity and self-selectivity. The first stage consists of the adoption decision model, to examine the adoption of GE crops as well as other pest management practices that might affect pesticide use. The adoption decision model allows estimation of predicted probabilities of adoption, to be used as in the second stage to account for simultaneity, as well as for correction factors for self-selection. The second stage estimates the impact of using GE crops on yields, farm net returns, and pesticide use.

As Use of Glyphosate Herbicides on Major Crops Rose in 1998, Other Herbicides Showed Decline



* Active ingredients
"Other" indicates herbicides other than glyphosates.
Source: Agricultural Resource Management Study, 1996-98.

Economic Research Service, USDA

Data indicate that adoption of herbicide-tolerant crops leads to substitution of glyphosate herbicides for previously used herbicides. Based on regression results for soybeans, an estimated 5.4 million pounds of glyphosate is substituted for 7.2 million pounds of other synthetic herbicides, such as imazethapyr, pendimethalin, and trifluralin.

Glyphosate has a half-life in the environment of 47 days, compared with 60-90 days for the herbicides it commonly replaces. The herbicides that glyphosate replaces are 3.4 to 16.8 times more toxic, according to a chronic risk indicator based on the EPA reference dose for humans. Thus, the substitution enabled by genetic modifications conferring herbicide tolerance on soybeans results in glyphosate replacing other synthetic herbicides that are at least 3 times as toxic and that persist in the environment nearly twice as long as glyphosate.

Assessing change in pesticide use associated with adoption of GE crops is confounded by the same difficulties associated with pesticide use generally. Comparison of different mixes of pesticides involves evaluating tradeoffs between the amounts used and the environmental characteristics, primarily toxicity and persistence. The answer to the simple question, “Does adopting genetically engineered crops for pest management reduce pesticide use?” lies not just in more or less but in more or less of what. AO

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