Adoption and Pesticide Use

A complete analysis of environmental benefits and risks of GE crop adoption is beyond the scope of this report as it would need to quantify a range of factors (such as soil, geology, vegetation, and weather conditions), and data are not available for many of them. This section explores the potential impacts on the environment from GE crops that occur via pesticide use and changes in tillage practices.

Changes in pesticide use associated with the adoption of GE crops are surely an important effect of GE crops (Royal Society, 1998; Henry A. Wallace Center, 2000). A poll of farmers and consumers in August 1999 indicated that 73 percent of consumers were willing to accept biotechnology as a means of reducing chemical pesticides used in food production. Also, 68 percent said that farm chemicals entering ground and surface water was a major problem (Farm Bureau/Philip Morris Gap Research, 2000). And more recently, a survey of consumer attitudes suggested that 70 percent of consumers would be likely to buy a variety of produce "if it had been modified by biotechnology to be protected from insect damage and required fewer pesticide applications" (IFIC Foundation, 2001).

Pesticide Use Patterns

Herbicides constitute the largest pesticide category in U.S. agriculture. Corn is the largest herbicide user, and 96 percent of the 62.2 million acres devoted to corn production in the 10 major corn-producing States were treated with more than 164 million pounds of herbicides in 1997 (USDA, NASS/ERS, 1998). Soybean production in the United States also uses a large amount of herbicides—97 percent of the 66.2 million soybean acres in the 19 major producing States were treated with more than 78 million pounds of herbicides in 1997 (USDA, NASS/ERS, 1998). Cotton production relies heavily upon herbicides to control weeds, often requiring applications of two or more herbicides at planting and postemergence herbicides later in the season (Culpepper and York, 1998). Close to 28 million pounds of herbicides were applied to 97 percent of the 13 million acres devoted to upland cotton production in the 12 major cotton-producing States in 1997 (USDA, NASS/ERS, 1998).[25]

Cotton production also uses a large amount of insecticides, with 77 percent of upland cotton acres (in the 12 major producing States) treated with 18 million pounds of insecticides in 1997 (USDA, NASS/ERS, 1998).[26] While only 30 percent of the corn acres received insecticides in the 10 major corn-producing States in 1997, the amount of these insecticides exceeded 13 million pounds (USDA, NASS/ERS, 1998).

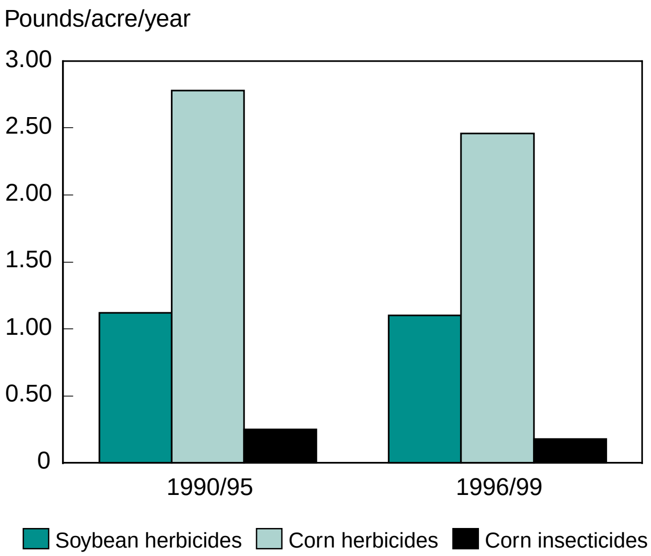
Pesticide use on corn and soybeans has declined since the introduction of GE corn and soybeans in 1996 (fig. 9). Field tests and enterprise studies have analyzed the agronomic, environmental, and economic effects of adopting GE crops, including actual pesticide use changes associated with using GE crops (McBride and Brooks, 2000; Fernandez-Cornejo, Klotz-Ingram, and Jans, 1999, 2002; Giannessi and Carpenter, 1999; Culpepper and York, 1998; Marra et al., 1998; Falck-Zepeda and Traxler, 1998; Fernandez-Cornejo and Klotz-Ingram, 1998; Gibson et al., 1997; ReJesus et al., 1997; Stark, 1997). Many of these studies have suggested that insecticide use has (or will) decline with the adoption of Bt varieties and that herbicide use is reduced with herbicide-tolerant varieties.

[25] Atrazine was the top herbicide used in corn in 1997, as farmers applied more than 47 million pounds of this chemical. Metolachlor was second (nearly 44 million pounds applied), followed by acetochlor (28 million pounds) and cyanazine (16 million pounds). Pendimethalin was the top herbicide used on soybeans, as farmers applied more than 17 million pounds in 1997. Glyphosate, use of which grew substantially over 1996 levels, was second (15 million pounds), followed by trifuralin (12 million pounds) and metolachlor (9 million pounds). Increased use of glyphosate has corresponded with the growth of herbicide-tolerant crop programs that use glyphosate as the primary herbicide. Trifuralin was the top herbicide applied on cotton in 1997 (5.5 million pounds), followed closely by MSMA (4.9 million pounds) and fluometuron (4.9 million pounds) (USDA, NASS/ERS, 1998).

[26] Malathion was the top insecticide used on cotton, as farmers applied more than 7 million pounds of this chemical in 1997. Aldicarb was second (2.4 million pounds), followed by methyl parathion (2 million pounds), and acephate (0.9 million pounds). The top insecticides used on corn in 1997 were chlorpyrifos (5.3 million pounds), terbufos (3.2 million pounds), methyl parathion (1.5 million pounds), and carbofuran (1.5 million pounds) (USDA, NASS/ERS, 1998).

Figure 9

Pesticide use, 1990-99



Sources: Fernandez-Cornejo (2000) based on USDA data (USDA, 1991, 1992, 1993, 1994, 1995, 1996, 1997c, 1998b, 1999a, 2000a).

The use of Bt varieties has led to reductions in those insecticides previously used to treat the pests targeted by Bt. However, conventional insecticides targeting insects not affected by the toxin continue apace. With herbicide-tolerant crops, which facilitate the use of a particular herbicide such as glyphosate, adoption simply involves substitution, changing the mix of herbicides used in the cropping system.

Pesticide Measurement Issues

The ARMS provides cross-sectional data on pesticide use by producers who do and do not adopt GE crops for each year since 1996. Using the ARMS data, one could simply compare the mean pesticide use among current adopters and nonadopters of GE crops. However, differences in characteristics that affect the adoption decision may influence pesticide use decisions as well, making these simple comparisons suspect (Fernandez-Cornejo and McBride, 2000). The challenge is to find a way to control for all other sources of variation in pesticide use so that the adoption impact can be isolated. In short, what pesticides would have been used in the given year in the absence of GE adoption?

In light of this and other issues, our analysis is based on an econometric model that statistically controls for other factors that may affect pesticide use (Fernandez-Cornejo, Klotz-Ingram, and Jans, 1999). The econometric results are expressed in terms of elasticities that represent marginal changes in pesticide use for a small increase in the adoption of GE crops. These elasticities are used to calculate the changes in acre-treatments associated with the changes in adoption between 1997 and 1998 for herbicide-tolerant soybeans and cotton and Bt cotton, and between 1996 and 1997 for herbicide-tolerant corn (Heimlich et al., 2000a,b). Pesticide use data for Bt corn were unavailable. The changes in pounds of active ingredients used associated with changes in GE crop adoption are similarly calculated, but require the assumption that the rate of application remains constant as the number of acre-treatments changes.[27]

Impact of Adoption on Pesticide Use

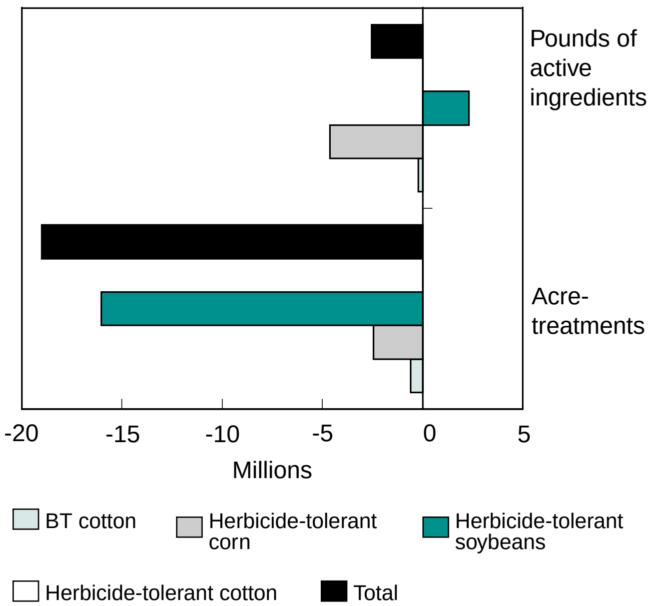
Our analysis shows an overall reduction in pesticide use related to the increased adoption of GE crops (Bt cotton, and herbicide-tolerant corn, cotton, and soybeans; Bt corn data were not available). The decline in pesticide use was estimated to be 19.1 million acre-treatments, 6.2 percent of total treatments (fig. 10). These estimates are associated with the changes in adoption that occurred between 1997 and 1998 (except for herbicide-tolerant corn, which is modeled for 1996-97). While such changes would normally be small over a single year, the spectacular growth in biotech crop use meant that adoption increased by 160 percent for herbicide-tolerant soybeans, 150 percent for herbicide-tolerant cotton, 12 percent for Bt cotton, and 43 percent for herbicide-tolerant corn. Most of the decline in pesticide acre-treatments was from less herbicide used on soybeans, accounting for more than 80 percent of the reduction (16 million acre-treatments).

The estimated active ingredients applied to corn, soybean, and cotton fields also declined by about 2.5 million pounds, altough the total herbicide pounds used on soybeans actually increased as glyphosate was substituted for conventional herbicides. Once the results are broken down by type of herbicide, the data indicate that an estimated 13.4 million pounds of glyphosate substituted for 11.1 million pounds of other synthetic herbicides.[28]

[27] This is a conservative assumption. See also note 28.

[28] As noted before, this estimate assumes constant application rates. Additional econometric estimates for adoption of herbicide-tolerant soybeans, relaxing the constant-rate assumption, showed a minimal change in the total pounds of herbicide active ingredients resulting from the substitution of glyphosate for other herbicides (Fernandez-Cornejo, Klotz-Ingram, and Jans, 2002).

Figure 10
Change in pesticide use, 1997-98



Note: Change in pesticide use from the adoption of herbicide-tolerant cotton was not significant.

Source: USDA (Heimlich et al. 2000b).

Pesticide Toxicity and Persistence

The changing mix of pesticides that accompanies adoption complicates the analysis because toxicity and persistence in the environment vary across pesticides. The term herbicide or insecticide refers to a multitude of heterogeneous products. Thousands of formulations (commercial forms in which the pesticide is sold) are used. These formulations are mixtures of active chemicals (active ingredients) and inert materials, used to improve safety and facilitate storage, handling, or application. Hundreds of chemical products are used as active ingredients. Each active ingredient has not only a different spectrum of pest control and potency, but also has a different impact on human health and the environment (Fernandez-Cornejo and Jans, 1995). Given this, it seems insufficient to report pesticide use by adding the quantities of all pesticides applied, even if expressed in pounds of active ingredient. For this reason, other measures are used such as acre-treatments and proxies for the "impact" of pesticides on human health and the environment.

Consider the most widely used GE crop, herbicide-tolerant soybeans. The adoption of herbicide-tolerant soybeans leads to the substitution of glyphosate for previously used herbicides. These crops are designed to allow farmers to limit herbicide treatments to as few as a single postemergence application of glyphosate, while a conventional weed control program can involve multiple applications of several herbicides. In addition, and more importantly, herbicide-tolerant crops often allow farmers to use more benign herbicides.

Glyphosate binds to the soil rapidly, preventing leaching, and is biodegraded by soil bacteria (Malik et al., 1989). In fact, glyphosate has a half-life in the environment of 47 days (Wauchope et al., 1993), compared with 60-90 days for the herbicides it commonly replaces. In addition, glyphosate has extremely low toxicity to mammals, birds, and fish (Malik et al., 1989). 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 caused by the use of herbicide-tolerant soybeans results in glyphosate replacing other synthetic herbicides that are at least three times as toxic and that persist in the environment nearly twice as long.

Soil Losses and Runoff

Availability, since the 1980s, of postemergent herbicides that could be applied over a crop during the growing season has facilitated the use of no-till farming practices, since weeds could be controlled after crop growth without tilling the soil. The use of herbicide-tolerant crops (particularly soybeans) has intensified that trend since it often allows a more effective and less costly weed control regime than using other postemergent herbicides (Carpenter and Gianessi, 1999).

The impact of conservation tillage (including no-till, ridge-till, and mulch-till) in controlling soil erosion and soil degradation is well documented (Edwards, 1995; Sandretto, 1997). By leaving substantial amounts of residue evenly distributed over the soil surface, conservation tillage (1) reduces soil erosion by wind; (2) reduces soil erosion by water (by reducing the kinetic impact of rainfall); (3) increases water infiltration and moisture retention; (4) reduces surface sediment and water runoff; and (5) reduces chemical runoff. Thus, by facilitating the use of conservation tillage (or no-till in particular), the adoption of herbicide-tolerant crops may reduce soil losses and runoff. However, there is little empirical evidence on how GE crops have affected tillage (Ervin et al., 2000).

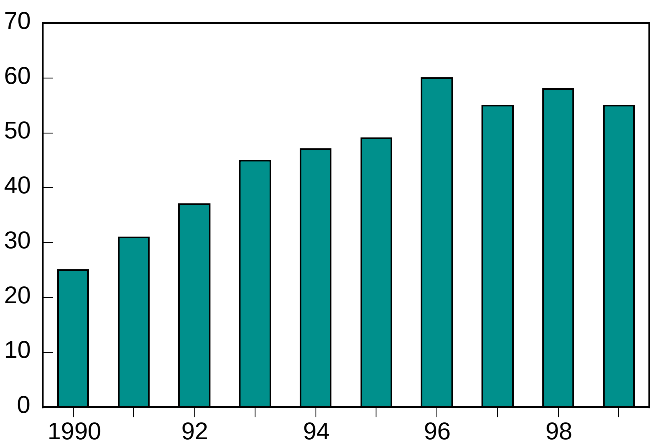
Adoption of conservation tillage for soybeans grew (at a decreasing rate) from about 25 percent of the soybean acreage in 1990 to 48 percent in 1995 (fig. 11), the 5-year period previous to the introduction of herbicide-tolerant soybeans. Growth of conservation tillage increased further in 1996, but then appears to have stagnated between 50 and 60 percent in the following years.

A larger portion of the acreage planted with herbicide-tolerant soybeans was under conservation tillage than was acreage growing conventional soybeans. According to estimates based on USDA's ARMS data, about 60 percent of the area planted with herbicide-tolerant soybeans was under conservation tillage in 1997 (fig. 12). In comparison, only about 40 percent of the acres planted with conventional soybeans were under conservation tillage the same year. Differences in use of no-till between adopters and nonadopters of herbicide-tolerant soybeans are even more pronounced: 40 percent of acres planted with herbicide-tolerant soybeans were under no-till, twice the corresponding share of farmers planting conventional soybeans.

Despite the relationship between conservation tillage and adoption of herbicide-tolerant crops, cause and

Figure 11

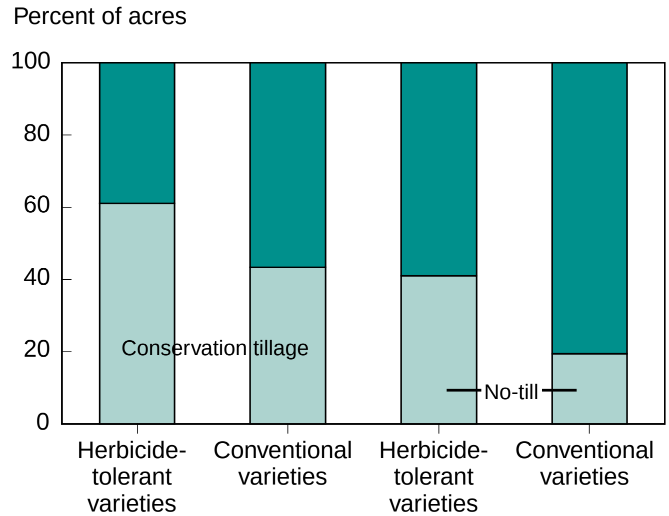
Use of conservation tillage - soybeans



Source: Fernandez-Cornejo (2000) based on USDA data (USDA, 1997a updated from ARMS).

Figure 12

Area under conservation tillage and no-till, soybeans 1997



Source: ARMS data.

effect is uncertain. Availability of the herbicide-tolerant technology may boost conservation tillage, while the use of conservation tillage may predispose farmers to adopt herbicide-tolerant seeds. Therefore, the two decisions must be considered simultaneously. An econometric model to address the simultaneous nature of these decisions (Soule and Klotz-Ingram, 2000) is used to determine the nature of the relationship between the adoption of herbicide-tolerant soybeans and no-till practices (appendix IV).

According to the econometric model results, using 1997 ARMS survey data, farmers using no-till for soybeans were found to have a higher probability of adopting herbicide-tolerant seed, but using herbicide-tolerant seed did not significantly affect no-till adoption. This result seems to suggest that farmers already using no-till found herbicide-tolerant seeds to be an effective weed control mechanism that could be easily incorporated into their weed management program. On the other hand, the commercialization of herbicide-tolerant soybeans did not seem to have encouraged adoption of no-till, at least the year of the survey, 1997.