Adoption of GE Crops by U.S. Farmers Increases Steadily

Farmers are more likely to adopt new practices and technologies if they expect to benefit from them. Benefits are usually thought of in monetary terms, but can also include ease of operation, time savings, lower exposure to chemicals, and other factors. Farmers choose technologies and practices they expect to yield the greatest benefit based on their own preferences, farm characteristics, demand for their product, and costs.

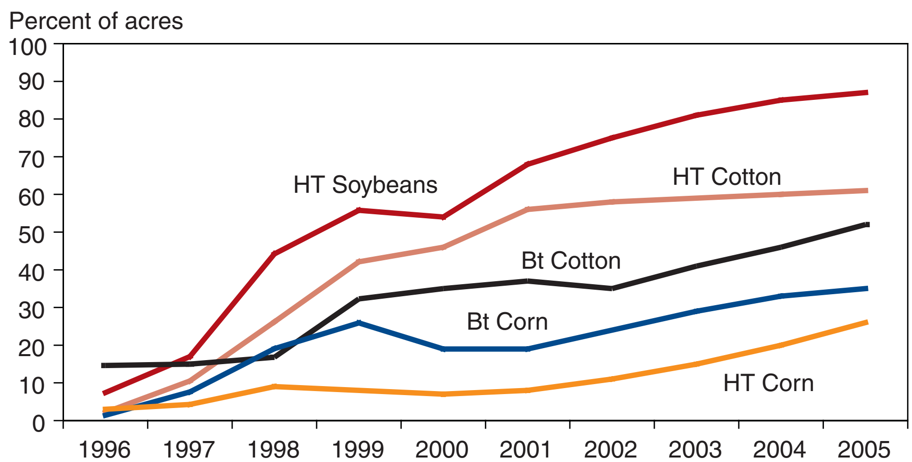
Farmers' expectations of higher yields, savings in management time, and lower pesticide costs have driven a rapid increase in the adoption of GE crop varieties in the United States and several other countries. An estimated 200 million acres of GE crops with herbicide tolerance and/or insect resistance traits were cultivated in 17 countries worldwide in 2004, a 20-percent increase over 2003. U.S. acreage accounts for 59 percent of this amount, followed by Argentina (20 percent), Canada and Brazil (6 percent each), and China (5 percent) (ISAAA, 2004).[3]

GE varieties of soybeans, corn, and cotton have been available commercially in the United States since 1996, and the rate of adoption by U.S. farmers has climbed in most years since then (fig. 6). For the most part, farmers have adopted herbicide-tolerant (HT) varieties—which help control weeds by enabling crops to survive certain herbicides that previously would have destroyed them along with the targeted weeds—at a faster pace than insect-resistant (Bt) varieties.

Weeds are such a pervasive pest for soybeans, corn, and cotton that over 90 percent of U.S. planted acreage for each crop has been treated with herbicides in recent years. The acreage share for HT soybeans has expanded more rapidly than that for HT varieties of cotton and corn, reaching 87 percent of U.S. soybean acreage in 2005.

Figure 6

Adoption of genetically engineered crops grows steadily in the U.S.*



*Data for each crop category include varieties with both HT and Bt (stacked) traits.
Source: Fernandez-Cornejo (2005).

[3]Also, there has been an upward trend in the adoption of "stacked gene" varieties (with traits of herbicide tolerance and insect resistance) in the case of cotton and corn.

Insect-resistant crops contain a gene from the soil bacterium *Bacillus thuringiensis* (Bt) that produces a protein toxic to specific insects. Acreage shares for Bt cotton and corn are lower than those for HT soybeans and cotton, and adoption is more concentrated in areas with a high level of infestation of targeted pests (insect infestation varies much more widely across locations than does weed infestation). Farmers planted Bt cotton to control tobacco budworm, bollworm, and pink bollworm on 52 percent of U.S. cotton acreage in 2005. Bt corn, originally developed to control the European corn borer, was planted on 35 percent of corn acreage in 2005, up from 24 percent in 2002. The recent increase in acreage share may be largely due to the commercial introduction in 2003/04 of a new Bt corn variety that is resistant to the corn rootworm, a pest that may be even more destructive to corn yield than the European corn borer (Comis).

Other GE crops planted by U.S. farmers over the past 10 years include HT canola, virus-resistant papaya, and virus-resistant squash (table 2). In addition, Bt potato varieties were introduced in 1996 but withdrawn from the market after the 2001 season, and a tomato variety genetically engineered to remain on the vine longer and ripen to full flavor after harvest was introduced in 1994 but was withdrawn from the market after being available sporadically for several years.

U.S. Farmers Expect To Profit From Adopting GE Crops

According to USDA's Agricultural and Resource Management Surveys (ARMS) conducted in 2001-03, most of the farmers adopting GE corn, cotton, and soybeans indicated that they did so mainly to increase yields through improved pest control (fig. 7). Other popular reasons for adopting GE crops were to save management time and make other practices easier and to decrease pesticide costs. These results confirm other studies showing that expected profitability increases through higher yields and/or lower costs (operator labor, pesticides) positively influence the adoption of agricultural innovations.

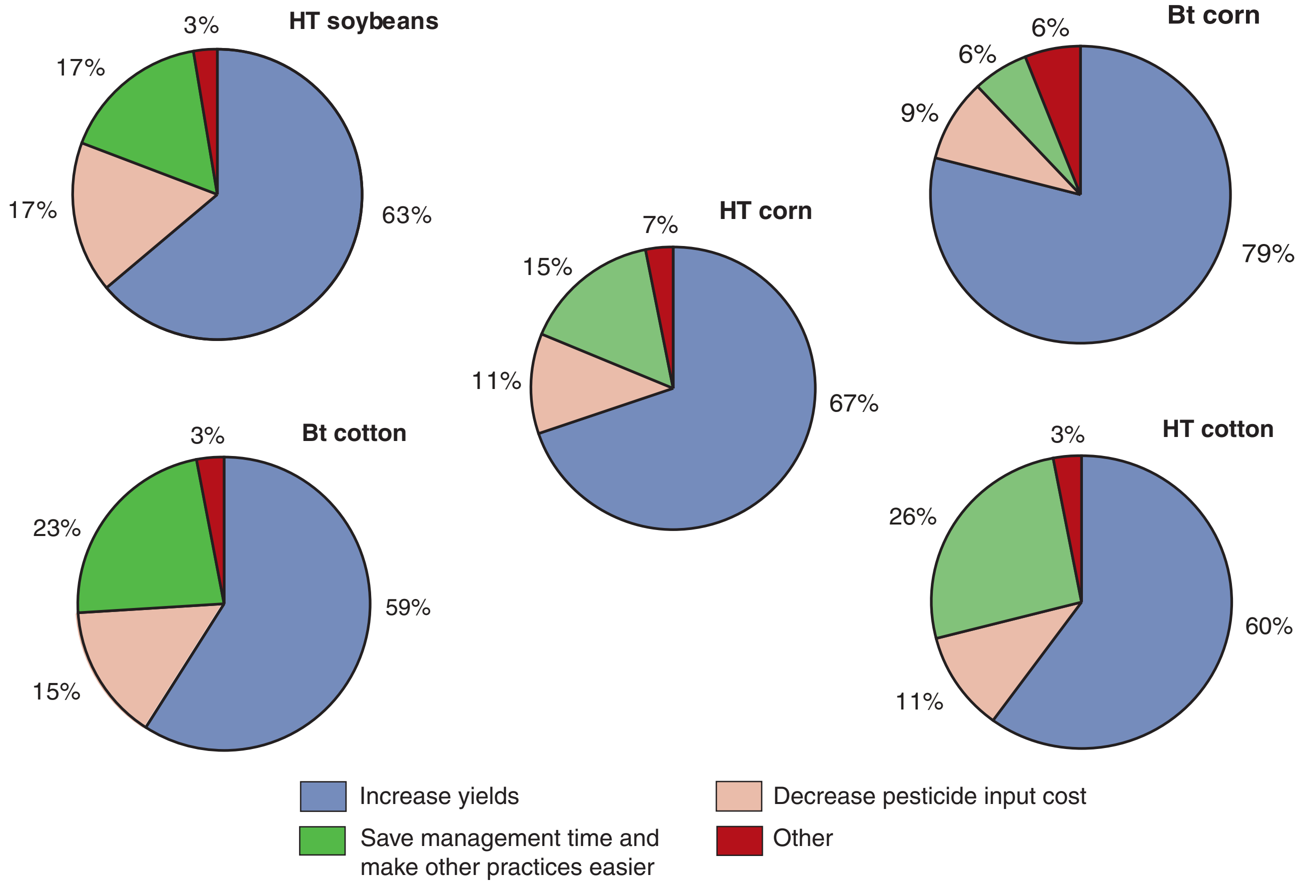
Adoption of GE Crops and Yields

Currently available GE crops do not increase the yield potential of a hybrid variety. In fact, yield may even decrease if the varieties used to carry the herbicide-tolerant or insect-resistant genes are not the highest yielding cultivars.[4] However, by protecting the plant from certain pests, GE crops can prevent yield losses compared with non-GE hybrids, particularly when pest infestation is high. This effect is particularly important for Bt crops. For example, before the commercial introduction of Bt corn in 1996, the European corn borer was only partially controlled using chemical insecticides. Chemical use was not always profitable, and timely application was difficult. Many farmers accepted yield losses rather than incur the expense and uncertainty of chemical control. For those farmers, the use of Bt corn resulted in yield gains rather than pesticide savings. On the other hand, a recently introduced Bt corn trait selected for resistance against the corn rootworm, previously controlled using chemical insecticides, may provide substantial insecticide savings.[5]

[4]This yield decrease occurred mostly in early years. HT or Bt genes were introduced into high-yielding cultivars in later years.

[5]Entomologists estimate that the corn rootworm causes up to $1 billion in corn yield losses and insecticide expenditures annually in the U.S. (Comis).

Figure 7
Farmers' reasons for adopting GE crops



Source: Compiled by USDA's Economic Research Service using data from 2001, 2002, and 2003 Agricultural Resource Management Survey.

Many field tests and farm surveys have examined the yield and cost effects of using GE crops (table 3). The majority of the results show GE crops produce higher yields than conventional crops.

A 2002 ERS study found that increases in cotton yields in the Southeast were associated with the adoption of HT and Bt cotton in 1997—a 10-percent increase in HT cotton acreage led to a 1.7-percent increase in yield and a 10-percent increase of Bt cotton acreage led to a 2.1-percent increase in yield. Increases in soybean yields associated with the adoption of HT soybeans were statistically significant but small (Fernandez-Cornejo and McBride, 2002).[6]

A more recent ERS study using 2001 survey data found that, on average, actual corn yield was 12.5 bushels per acre higher for Bt corn than for conventional corn, an increase of 9 percent (Fernandez-Cornejo and Li, 2005).[7]

Adoption and Net Returns, Household Income, and Pesticide Use

The impacts of GE crop adoption on U.S. farmers vary by crop and technology. Many studies have assessed the effects of the adoption of GE crops

[6]The study used an econometric model that takes into consideration that farmers' adoption of GE crops and pesticide use decisions may be simultaneous and that farmers are not assigned randomly to the two groups (adopters and nonadopters) but that they make the adoption choices themselves. Therefore, adopters and nonadopters may be systematically different. Differences may manifest themselves in farm performance and could be confounded with differences due to adoption. This self-selectivity may bias the results, unless corrected. To account for simultaneity and self-selectivity, the model uses a two-stage econometric model.

[7]In addition, results using an econometric model with the 2001 data showed a small but statistically significant yield increase associated with farmers who adopted Bt corn relative to those using conventional corn varieties. (Fernandez-Cornejo and Li, 2005).

on returns and pesticide use, and the results of these studies are summarized in table 3. ERS researchers found that:

Planting HT cotton and HT corn was associated with increased producer net returns, but HT corn acreage was limited.[8] The limited acreage on which HT corn has been adopted is likely to be acreage with the greatest comparative advantage for this technology. The positive financial association with adoption may also be due to low premiums for HT corn seed relative to conventional varieties in an attempt to expand market share (Fernandez-Cornejo and McBride, 2002).

[8]Net returns equal revenues minus variable costs, which include pesticide and seed costs. Seed costs paid by adopters of GE varieties include a technology fee paid by farmers to biotechnology developers and premiums to seed firms.

Adoption of Bt cotton and corn was associated with increased returns when pest pressures were high. The adoption of Bt cotton had a positive association with producer net returns in 1997, but the association was negative for Bt corn in 1998. This suggests that Bt corn may have been used on some acreage where the (ex post) value of protection against the European corn borer was lower than the premium paid for the Bt seed. Because pest infestations vary from one region to another and from one year to another, the economic benefits of Bt corn are likely to be greatest where pest pressures are most severe. Farmers must decide to use Bt corn before they know what the European corn borer pest pressure will be that year, and damage caused by the European corn borer varies from year to year. Some farmers may have incorrectly forecast infestation levels, corn prices, and/or yield losses due to pest infestations, resulting in “overadoption.” Also, producers may be willing to pay a premium for Bt corn because it reduces the risk of significant losses if higher-than-expected pest damage does occur (Fernandez-Cornejo and McBride, 2002).

Despite the rapid adoption of HT soybeans by U.S. farmers, no significant association with net farm returns was evident in 1997 or 1998. The lack of increased profitability for some farmers who adopted HT soybeans suggests that factors other than those included in traditional farm returns calculations may be driving adoption for these farmers. In particular, weed control may become simpler and require less management time, which allows growers of HT soybeans to control a wide range of weeds and makes harvest easier and faster. One important alternative use of management time is off-farm employment by farm operators and their spouses (Fernandez-Cornejo and McBride, 2002).

Adoption of HT soybeans is associated with increased household income. Recent ERS research showed that adoption of HT soybeans was associated with a significant increase in off-farm household income for U.S. soybean farmers. On-farm household income is not significantly associated with adoption but total farm household income is significantly higher for adopters, suggesting that most managerial time saved by adopters is used in off-farm work (Fernandez-Cornejo et al., 2005).

Adoption of GE crops is associated with reduced pesticide use. Pesticide use rates (in terms of active ingredient) on corn and soybeans have declined since the introduction of GE corn and soybeans in 1996 (fig. 8). In addition, ERS research suggests that, controlling for other factors, pesticide use declined with adoption. There was an overall reduction in pesticide use associated with the increased adoption of GE crops (Bt and HT cotton, HT

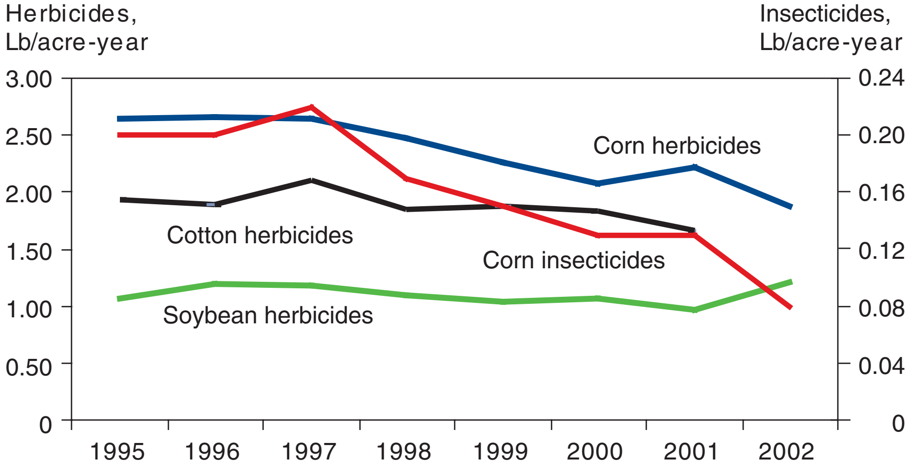
Table 3
Summary of primary studies on the effects of genetically engineered crops on yields, pesticide use, and returns

Crop/researchers/ date of publication	Data source	Effects on Yield	Effects on Pesticide use	Effects on Returns
Herbicide-tolerant soybeans				
Delannay et al., 1995	Experiments	Same	na	na
Roberts et al., 1998	Experiments	Increase	Decrease	Increase
Arnold et al., 1998	Experiments	Increase	na	Increase
Marra et al., 1998	Survey	Increase	Decrease	Increase
Fernandez-Cornejo et al., 2002[1]	Survey	Small increase	Small increase	Same
McBride & El-Osta, 2002[2]	Survey	na	na	Same
Duffy, 2001	Survey	Small decrease	na	Same
Herbicide-tolerant cotton				
Vencill, 1996	Experiments	Same	na	na
Keeling et al., 1996	Experiments	Same	na	na
Goldman et al., 1998	Experiments	Same	na	na
Culpepper and York, 1998	Experiments	Same	Decrease	Same
Fernandez-Cornejo et al., 2000[1]	Survey	Increase	Same	Increase
Herbicide-tolerant corn				
Fernandez-Cornejo and Klotz-Ingram, 1998	Survey	Increase	Decrease	Same
McBride & El-Osta, 2002[2]	Survey	na	na	Increase
Bt cotton				
Stark, 1997	Survey	Increase	Decrease	Increase
Gibson et al., 1997	Survey	Increase	na	Increase
ReJesus et al., 1997	Experiments	Same	na	Increase
Bryant et al., 1999[3]	Experiments	Increase	na	Increase
Marra et al., 1998	Survey	Increase	Decrease	Increase
Fernandez-Cornejo et al., 2000[1]	Survey	Increase	Decrease	Increase
Bt corn				
Rice and Pilcher, 1998	Survey	Increase	Decrease	Depends on infestation
Marra et al., 1998	Survey	Increase	Decrease	Increase
Benbrook, 2001	Survey	Increase	na	Decrease
McBride & El-Osta, 2002[2]	Survey	na	na	Decrease
Duffy, 2001	Survey	Increase	na	Same
Pilcher et al., 2002	Survey	Increase	Decrease	na
Baute, Sears, and Schaafsma, 2002	Experiments	Increase	na	Depends on infestation
Dillehay et al., 2004[4]	Experiments	Increase	na	na
Fernandez-Cornejo & Li, 2005[5]	Survey	Increase	Decrease	na

na = not analyzed in the study.
[1]Results using 1997 data.
[2]Results using 1998 data.
[3]Results are for 1996 and 1998. Results were different in 1997 when pest pressure was low.
[4]Results using 2000-2002 data.
[5]Results using 2001 data.
[6]Net returns equal revenues minus variable costs.

Figure 8

Pesticide use in major field crops



Source: NASS surveys.

corn, and HT soybeans combined, using 1997/1998 data), resulting in a significant reduction in potential exposure to pesticides (Fernandez-Cornejo and McBride, 2002). Overall pesticide use on corn, soybeans, and cotton declined by about 2.5 million pounds, despite the slight increase in the amount of herbicides applied to soybeans. In addition, glyphosate used on HT crops is less than one-third as toxic to humans, and not as likely to persist in the environment as the herbicides it replaces (Fernandez-Cornejo and McBride, 2002).

More recently, using 2001 data, ERS found that insecticide use was 8 percent lower per planted acre for adopters of Bt corn than for nonadopters (Fernandez-Cornejo and Li, 2005).[9]

The ERS results generally agree with field-test and other farm surveys that have examined the effects of using GE crops (table 3). The majority of those results show that pesticide use for adopters of GE crops is lower than for users of conventional varieties.

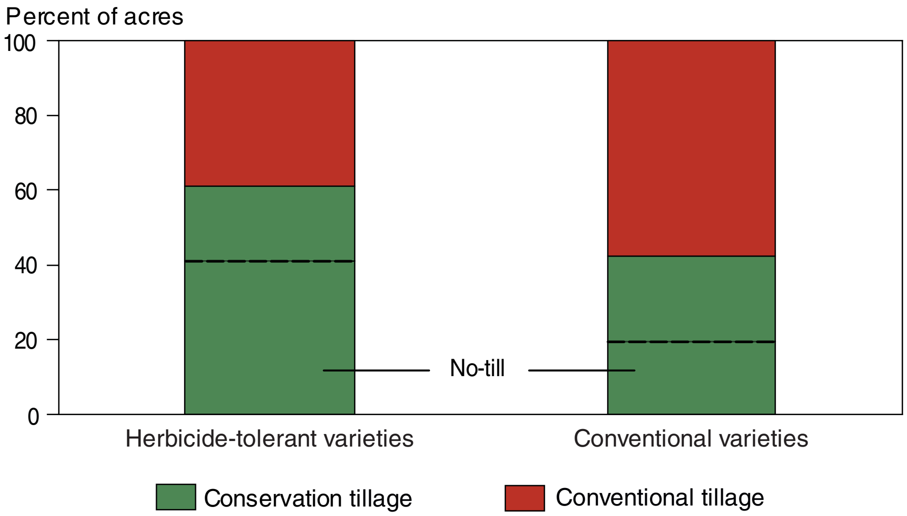
Adoption of HT soybeans appears to be associated with conservation tillage. The environmental impact of conservation tillage is well documented.[10] The use of conservation tillage reduces soil erosion by wind and water, increases water retention, and reduces soil degradation and water and chemical runoff.

According to USDA survey data, about 60 percent of the area planted with HT soybeans was under conservation tillage in 1997, compared with only about 40 percent of the acres planted with conventional soybeans (fig. 9). Differences in the use of no-till between adopters and nonadopters of HT soybeans are even more pronounced: 40 percent of acres planted with HT soybeans were under no-till, twice the corresponding share of acreage planted with conventional soybeans. As a result, adoption of HT crops may indirectly benefit the environment by encouraging farmers to use soil conservation practices.

[9]In addition, using an econometric model with the 2001 data, the ERS study showed a moderate but statistically significant insecticide reduction associated with farmers who adopted Bt corn relative to those using conventional corn varieties (a 4.11-percent decrease in insecticide use was associated with a 10-percent increase in Bt corn adoption).

[10]Conservation tillage includes any tillage and planting system that leaves at least 30 percent of the soil surface covered with crop residue. It includes no-till, ridge-till, and mulch-till (Conservation Technology Information Center, 2004).

Figure 9
Soybean area under conservation tillage* and no-till, 1997



*Conservation tillage acres includes acres under no-till, ridge till, and mulch-till systems.
Source: Fernandez-Cornejo and McBride (2002).