

# The Extent of Adoption of Bioengineered Crops

## Herbicide-Tolerant Crops

The mostly widely adopted bioengineered crops have been those with herbicide-tolerant traits. These crops were developed to survive the application of specific herbicides that previously would have destroyed the crop along with the targeted weeds, and provide farmers a broader variety of herbicide options for effective weed control. The most common herbicide-tolerant crops are crops resistant to glyphosate, an herbicide effective on many species of grasses, broadleaf weeds, and sedges. Glyphosate tolerance has been incorporated into soybeans, corn, canola, and cotton. Other GE herbicide-tolerant crops include corn that is resistant to glufosinate-ammonium, and cotton that is resistant to bromoxynil.<sup>2</sup>

The adoption of most herbicide-tolerant crops has been particularly rapid. Herbicide-tolerant soybeans became available to farmers for the first time in limited quantities in 1996. Use expanded to about 17 percent of the soybean acreage in 1997, to 56 percent in 1999, and to 68 percent in 2001 (fig. 1). Herbicide-tolerant cotton expanded from 10 percent of cotton surveyed acreage in 1997, to 42 percent in 1999, and to 56 percent in 2001.<sup>3</sup> To contrast, the adoption of herbicide-tolerant corn has been much slower, reaching a plateau at 8-9 percent of corn acreage in 1998-2001 (see box 1 for a description of the data used to obtain the adoption estimates).

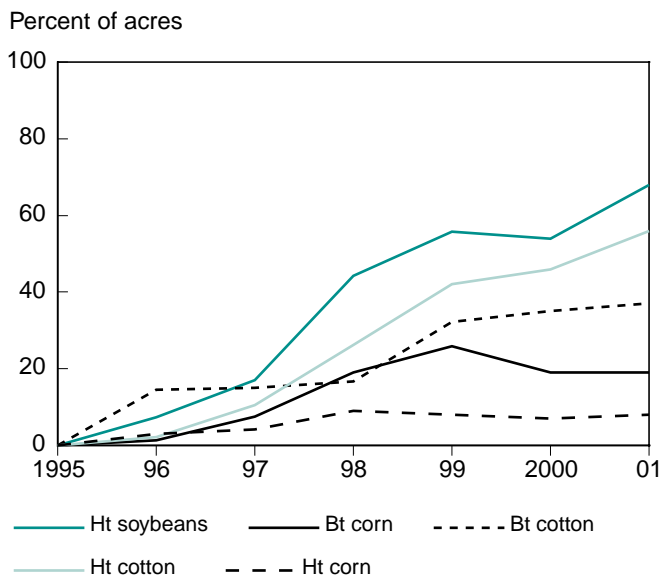
## Insect-Resistant Crops

Crops inserted with insect-resistant traits have also been widely adopted. Bt crops containing the gene from a soil bacterium, *Bacillus thuringiensis*, are the

<sup>2</sup> In addition to GE crops, there are traditionally bred herbicide-tolerant crops, such as corn resistant to imidazolinone (IMI) and sethoxydim (SR), and soybeans resistant to sulfonylurea (STS).

<sup>3</sup> For the case of corn and cotton, acres of crops with stacked traits (containing both Bt and herbicide-tolerant traits) are counted as acres in each category.

Figure 1  
Adoption of GE crops in the United States



Source: Fernandez-Cornejo (2000) based on USDA data (Fernandez and McBride, 2000; USDA 1999b, 2000b, 2001).

only insect-resistant crops commercially available. The bacteria produce a protein that is toxic when ingested by certain Lepidopteran insects (insects that go through a caterpillar stage). The Bt technology is a novel approach to controlling insects because the insecticide is produced throughout the plant over its entire life. Therefore, the insecticide is more effective than conventional and biological insecticides because it cannot be washed off by rain or broken down by other environmental factors. Bt has been built into several crops, including corn and cotton.

Bt corn provides protection mainly from the European corn borer. The Environmental Protection Agency (EPA) approved Bt corn in August 1995, and its use grew to about 8 percent of the corn acreage in 1997 and to about 26 percent in 1999, before receding to 19 percent in 2000-01 (fig. 1). Bt cotton is primarily effective in controlling the tobacco budworm, the bollworm, and the pink bollworm. Use of Bt cotton expanded to 15 percent of cotton acreage in 1997, to 32 percent in 1999, and to 37 percent in 2001.

## Box 1—USDA Survey Data

The USDA surveys that provided agricultural production data—including the adoption of genetically engineered (GE) corn, cotton, and soybeans used in this report—are the Agricultural Resource Management Study (ARMS) surveys (data used for 1996-98), the Objective Yield Survey (results used for 1999), and the June Agricultural Survey (results used for 2000).

**1996-98 Data - The NASS/ERS ARMS Surveys.** The Agricultural Resource Management Study (ARMS) surveys developed by the Economic Research Service (ERS) and the National Agricultural Statistics Service (NASS) of USDA are conducted each year starting from 1996. The ARMS survey is designed to link data on the resources used in agricultural production to data on use of technologies (including the use of genetically engineered crops), other management techniques, chemical use, yields, and farm financial/economic conditions for selected field crops. Each survey included three phases (screening, obtaining production practices and cost data, and obtaining financial information). As shown in the accompanying table, the number of (major) States covered by the surveys varies by crop and year, but each survey includes States that account for between 79 and 96 percent of U.S. acreage in the specified crop.

The ARMS is a multi-frame, probability-based survey in which sample farms are randomly selected from groups of farms stratified by attributes such as economic size, type of production, and land use. Each selected farm represents a known number of farms with similar attributes. Weighting the data for each surveyed farm by the number of farms it represents is the basis for calculating estimates for all U.S. farms.

The adoption data results for 1998-99 from ARMS have been summarized and reported (Fernandez-Cornejo and McBride, 2000) using the new set of farm resource regions depicting geographic specialization in production of U.S. farm commodities recently constructed by ERS (USDA, ERS, 1999). The eight farm-resource regions recognize both new capabilities and standards in the resolution of relevant

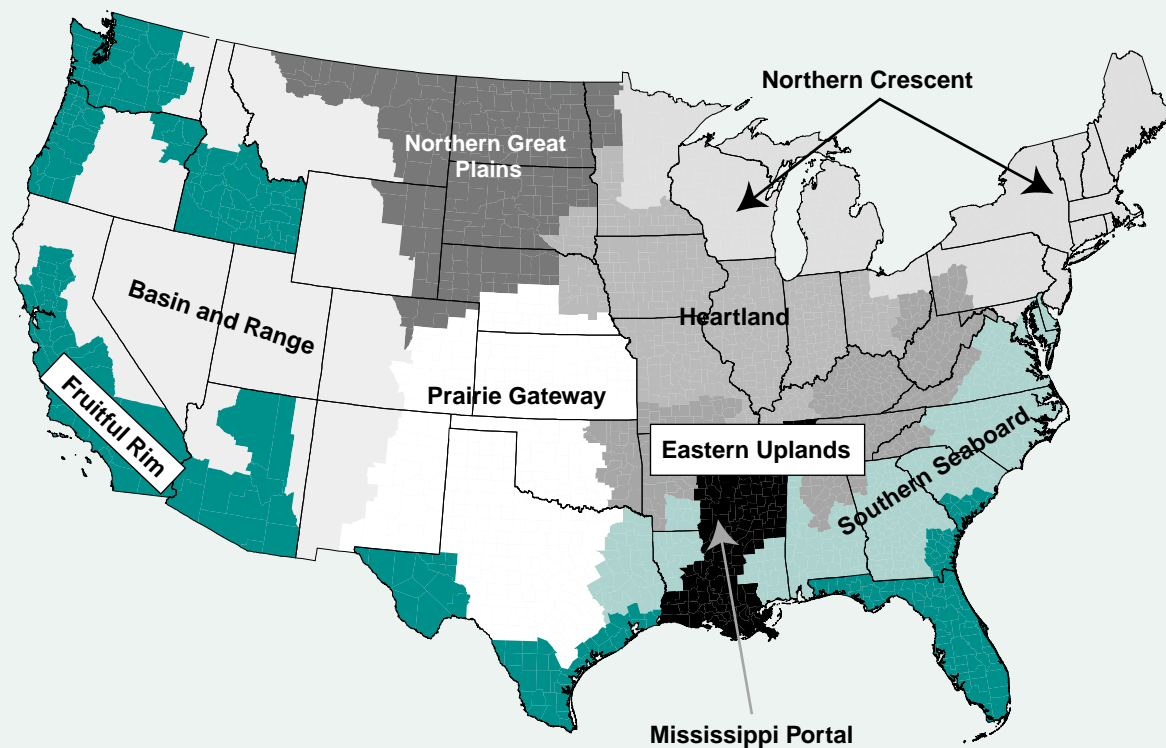
data, and overcome some longstanding problems with the older USDA Farm Production Regions. In constructing the farm resource regions, ERS analysts identified where areas with similar types of farms intersected with areas of similar physiographic, soil, and climatic traits, as reflected in USDA's Land Resource Regions. A U.S. map depicting the regions is shown in the figure below.

**1999 Data - The NASS Objective Yield Survey.** The 1999 adoption data are based on responses from the seed variety questions on the 1999 objective yield and farm operator survey conducted between September and October to gather information on expected yields. The information was published in the report titled *Crop Production* (USDA, NASS, 1999c). The objective yield surveys (OYS) for corn, soybeans, and cotton were conducted in the major producing States that account for between 61 and 71 percent of the U.S. production (see accompanying table). NASS conducts objective yield surveys in major corn, soybean, and upland cotton producing States each year (USDA, NASS, 1999c). Randomly selected plots in corn for grain, soybean, and upland cotton fields are visited monthly from August through harvest to obtain specific counts and measurements. The farm operator survey was conducted primarily by telephone with some use of mail and personal interviewers. Approximately 15,000 producers were interviewed during the survey period and surveyed throughout the growing season to provide indications of average yields as the season progresses.

Detailed information concerning the selected fields is obtained during an initial producer interview. Respondents were asked if they planted seed that was resistant to herbicides or insects. Herbicide-tolerant varieties include those developed using both biotechnology or conventional breeding techniques. Insect-resistant varieties include those containing Bt. These data are intended to show trends in production practices but not official estimates of the Agricultural Statistics Board.

*continued on page 6*

## ERS Resource Regions



**USDA survey coverage in percent of area planted  
(number of States in parentheses)**

	ARMS <sup>1</sup>			OYS <sup>2</sup>		Acreage <sup>3</sup>
	1996	1997	1998	1998	1999	2000
Corn	88(16) <sup>4</sup>	77(10) <sup>5</sup>	89(16) <sup>6</sup>	61(7) <sup>7</sup>	62(7) <sup>7</sup>	100(All) <sup>8</sup>
Cotton	83(8) <sup>9</sup>	96(12) <sup>10</sup>	92(10) <sup>11</sup>	63(5) <sup>12</sup>	63(5) <sup>12</sup>	100(All) <sup>8</sup>
Soybeans	79(12) <sup>13</sup>	93(19) <sup>14</sup>	91(16) <sup>15</sup>	71(8) <sup>16</sup>	71(8) <sup>16</sup>	100(All) <sup>8</sup>

<sup>1</sup> ARMS: Agricultural Resource Management Study carried out by the USDA.

<sup>2</sup> OYS: Objective Yield Survey carried out by the USDA; percentages refer to area harvested.

<sup>3</sup> June Agricultural Survey published in the *Acreage* report (USDA, NASS, 2000b).

<sup>4</sup> IL, IN, IA, KS, KY, MI, MN, MO, NE, NC, OH, PA, SC, SD, TX, WI (reported in USDA, NASS/ERS, 1997).

<sup>5</sup> IL, IN, IA, MI, MN, MO, NE, OH, SD, WI (reported in USDA, NASS/ERS, 1998).

<sup>6</sup> CO, IL, IN, IA, KS, KY, MI, MN, MO, NE, NC, OH, PA, SD, TX, WI (reported in USDA, NASS/ERS, 1999).

<sup>7</sup> IL, IN, IA, MN, NE, OH, WI (reported in USDA, NASS, 1999c).

<sup>8</sup> All States included in the estimating program for the crop (reported in USDA, NASS, 2000b).

<sup>9</sup> AZ, AR, CA, GA, LA, MS, TN, TX (reported in USDA, NASS/ERS, 1997).

<sup>10</sup> AL, AZ, AR, CA, GA, LA, MS, MO, NC, SC, TN, TX (reported in USDA, NASS/ERS, 1998).

<sup>11</sup> AL, AZ, AR, CA, GA, LA, MS, NC, TN, TX (reported in USDA, NASS/ERS, 1999).

<sup>12</sup> AR, CA, LA, MS, TX (reported in USDA, NASS, 1999c).

<sup>13</sup> AR, IL, IN, IA, LA, MN, MS, MO, NE, OH, TN, WI (reported in USDA, NASS/ERS, 1997).

<sup>14</sup> AR, DE, IL, IN, IA, KS, KY, LA, MI, MN, MS, MO, NE, NC, OH, PA, SD, TN, WI (reported in USDA, NASS/ERS, 1998).

<sup>15</sup> AR, IL, IN, IA, KS, KY, LA, MI, MN, MS, MO, NE, NC, OH, SD, TN (reported in USDA, NASS/ERS, 1999).

<sup>16</sup> AR, IL, IN, IA, MN, MO, NE, OH (reported in USDA, NASS, 1999c).

continued on page 7

Continued from page 6

**2000 Data - The NASS June Agricultural Survey.**

The 2000 adoption data were collected as part of the June Agricultural Survey that NASS conducted the first 2 weeks of June and published on June 30, 2000, in the report titled *Acreage* (USDA, NASS, 2000b). These surveys are based on a probability area farm survey with a sample of about 10,800 segments or parcels of land (averaging approximately 1 square mile) and a probability sample of more than 77,700 farm operators. Enumerators conducting the area survey contact all farmers having operations within the sampled segments of land and account for their operations. Farmers in the list survey sample are contacted by mail, telephone, or personal interview to obtain information on their operations. Responses from the list sample, plus data from operations that were not on the list to be sampled, are combined to provide another estimate of planted and harvested acres (USDA, NASS, 2000b).

Regarding GE crops, during the first 2 weeks of June 2000, randomly selected farmers across the United States were asked if they planted seed that, through biotechnology, was resistant to herbicides, insects, or both (USDA, NASS, 2000b). Unlike previous surveys, herbicide-tolerant varieties in this survey include only those developed using biotechnology. Conventionally bred herbicide-tolerant varieties were excluded from the survey. Insect-resistant varieties include only those containing Bt. Stacked gene varieties include those containing GE traits for both herbicide and insect resistance.

**Comparability Among Surveys.** Data from the different USDA surveys are not directly comparable because of inconsistencies that arose because none of the surveys were specifically designed to collect data on genetically engineered varieties. Rather, questions on adoption of GE crops were added to different USDA survey instruments the main objective of which was other than measuring the extent of adoption of these crops. As a consequence, survey

coverage among surveys is often different. There are also some differences in the base acreage used to calculate the percentage of adoption, and the questions related to GE adoption are not identical in different surveys.

**Coverage.** As shown in the preceding table, coverage varies among the different surveys and crops. The Objective Yield Survey (OYS) appears to have the lowest coverage (61 percent of the acreage for corn in 1998) and the 2000 acreage survey the highest. The ARMS survey reached about 90 percent of the acreage for each of the three crops in 1998. Since NASS provided adoption information at State level for 2000, it is possible to calculate the ratio of the U.S. adoption rate of GE crops relative to the rate for States covered by the OYS. For 2000, these ratios are highest for Bt cotton (1.31) and herbicide-tolerant cotton (1.18). This means that a direct comparison of adoption rates using, for example, OYS data for 1999 and acreage survey data for 2000 may be misleading.

**Acres planted.** Unlike all other sources, which reported the adoption rates relative to planted acres, the objective yield survey reported the adoption rates relative to harvested acres. Since the ratio of planted to harvested acres ranges from 1.02 for soybeans to 1.25 for upland cotton (in 1998), a comparison of data reported with a different base may also be misleading.

**Questions.** The questions in the different surveys were not identical. An extreme example is the case of herbicide-tolerant crops. Adoption data for 1996-99 include herbicide-tolerant corn and soybeans obtained using traditional breeding methods (not GE) such as STS soybeans. The 2000 data, on the other hand, excluded these varieties. While adoption of these non-GE soybean varieties is known to be small (between 2 and 3 percent for the case of soybeans in Iowa), we do not know the precise amounts nationwide. Thus, no attempt was made to estimate this effect.