12/19/00 **Genetically and non-Genetically Modified Crops, How they are created, produced, and marketed**

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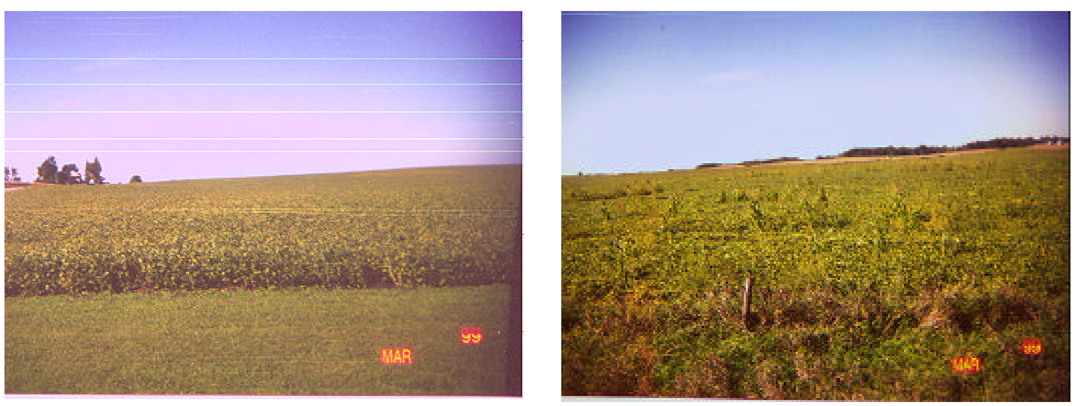
In 1997, transgenic varieties of soybean seed that resist the herbicide Round Up®[2] became widely available commercially in the U.S. and other parts of the world. The term, transgenic, indicates that a gene or genes from a non-related life-form have been transferred into the genetic structure of another life-form, in this case a soybean plant. While the term is not strictly accurate, the name "genetically modified organism (GMO)" has been widely accepted as the appropriate term for describing such crops. The procedure for developing these crops is in sharp contrast to plant breeding and genetic modification that have been done for centuries, in which genes from other related varieties were used to create improved varieties of a specific crop through plant breeding.

Farmers in the U.S. rapidly adopted GMO soybeans, resulting in the most rapid diffusion of new agricultural technology ever experienced. In 1997, less than 20 percent of the U.S. soybean cropland was believed to be planted to GMO varieties. By 1999, the percentage had increased to an estimated 57 percent, and in 2000 it is estimated at 54 percent. The photos below contrast the weed control effectiveness of Roundup Ready®[3] soybeans (left) with a non-GMO variety (right). For corn, an estimated 25 percent of the U.S. crop was estimated to have been planted to GMO varieties in 2000—down from about 33 percent the previous year.

Photo 1. Contrasts of Roundup Ready Soybeans (Left) and Weed Problems in a Conventional Variety (Right)



Benefits From GMOs

Those who supported the development of these new crops either financially or with professional research believe the new technology holds great potential for reducing global hunger and malnutrition through increased yields and improved quality. Future GMO products are projected to include crops with pharmaceutical benefits, vitamin-enhanced grains, and those with amino acids and other nutritional features that are better suited to human needs than current varieties. Crops with increased drought and extreme-temperature tolerance, and resistance to a variety of pests and diseases also are envisioned to be developed. However, at this time, the main types of GMO

[2,3] Roundup Ready is a registered trademark of Monsanto.

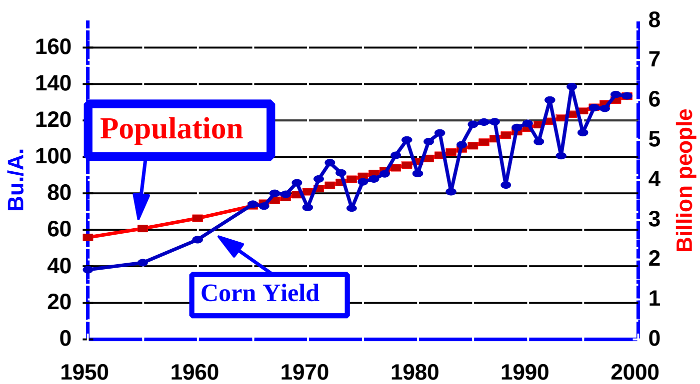
soybeans are those not damaged by the broad-spectrum herbicide, "Roundup". The active ingredient in Roundup is glyphosate, which kills nearly all weeds that normally are a problem in producing soybeans. For corn, the current GMO technology includes "Roundup Ready", "Bt" varieties or events, and stacked events or varieties that contain a combination of these two features. Bt corn was designed to resist corn borers, an insect that attacks and weakens the plant. The degree of corn borer infestation varies from year to year and by geographic location. It has tended to be a greater problem in U.S. Corn Belt areas west of the Mississippi river than in corn producing regions east of the Mississippi. "Liberty Link®[4]" GMO corn also is available, which resists the herbicide, Liberty®.

The photo of corn (maize) shows a perfect stalk and ear, undamaged by insects. By damaging the stalk and reducing yield potential, corn borers increase the risk that corn plants will fall over before they can be harvested, making the crop more vulnerable to damage from wind, and dropping of ears so that a part of the production cannot be harvested.

Photo 2. Insect-free Corn Plant and Ear.

Figure 1 shows the long-run trend in world population, along with global grain production. Population data come from the WorldWatch Institute and grain production numbers are USDA data. So far, world grain production has outpaced the increase in the global population through the use of non-GMO technology. However, the long-term ability of global agriculture to supply enough food for an expanding population is uncertain. Unabated population growth shows a continuing need for priority on agricultural research to increase yields, although the persistent supply increases of recent years have placed downward pressure on commodity prices. There is no indication that supply increases will be less robust in the future than in past decades, even without transgenic crops.

Figure 1. World Population & U.S. U.S. Corn Yield, 1950-1999



Today's Roundup Ready soybeans reduce the number of herbicides that farmers need to apply to control weeds, and facilitate minimum tillage or no-tillage farming. Reduced tillage or absence of tillage, in turn, reduces soil erosion and surface water contamination. Bt corn eliminates the need for use of insecticides that can cause various types of environmental contamination.

Who gains from GMOs?

In the very short run, innovative farmers who increase their crop yields by using GMOs are significant beneficiaries, along with companies selling the new technology. But, if the new technology increases production and is widely used, it is followed by lower prices and competition quickly transfers benefits away from farmers to consumers in the form of reduced food costs.

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[4] Liberty Link is a registered trademark of E. I. DuPont de Nemours & Co.

However, with the small share of the consumers' food expenditures accounted for by the raw farm products, most consumers will notice little or no gain from lower prices. For corn and soybeans, with all other market factors remaining constant, a one percent increase in supply will lower prices on average by about 2.0 and 2.5 percent, respectively. For GMO crops designed to add value for consumers, (unlike the Roundup Ready soybeans and Bt corn, which for most consumers have no perceived added value and for some have a perceived negative value), a net economic gain might be available for farmers. This gain could be reduced or dissipated over time with supply increases.

Reasons some groups are opposed to GMO crops

In several parts of the world, consumers and environmentalists have shown strong resistance to GMOs. For consumers, concerns appear to be centered on four main areas:

- Concern that U.S. government approval procedures may not adequately test for long-term safety of GMO-based foods
- Concern that inserting a foreign gene into a crop may produce unanticipated reactions within the plant that are hazardous to some or all consumers, and that these reactions may not be adequately identified by current testing procedures
- Concern that antibiotic-resistant marker genes in many GMO crops could have implications for human and animal health
- Concern about the small number of firms owning the GMO technology, with implications for future competitiveness of global food markets, food prices and the structure of agriculture---especially in lower-income developing nations where farmers cannot afford to buy commercial seed every year.

In late September of 2000, the GMO approval process came to the forefront in the U.S. A major fast-food chain, Taco Bell, and Kraft Foods, a supplier of corn products to retail food store chains was found through laboratory tests to have food products produced with a type of GMO corn (Starlink®)[5]approved only for animal feed. In response, Kraft Foods, promptly recalled the products in question, thus removing them from retail stores. Two weeks later, Starlink was found in taco products manufactured by a corn milling plant owned by ConAgra and Mission Foods. Mission Foods is the largest maker of tortillas, another type of Mexican food made with corn. Other U.S. food retailers that removed similar products from their stores included Kroger Co., Food Lion, Shaw's Supermarkets, and Albertson's, Inc. The Azteca corn milling company, where the problem was first discovered, supplies the flour for taco manufacturing and indicated it had purchased the unprocessed corn through contracts with farmers to produce non-GMO corn, and that the contamination may have come from cross-pollination from neighboring fields (Kilman).

In slightly over a week, the USDA and Aventis, the company selling the seed corn involved, made plans to segregate the corn from normal market channels and insure that it be used only for livestock feed or industrial purposes. Aventis also made the decision to stop selling Starlink corn. Seed companies selling this type of corn, along with approved varieties included AgriBioTech, Inc.; AgriPro Seeds, Inc.; Bo-Jac Seed Co.; Cenex/Croplan Genetics; Curry Seed Co.; Fred Gutwein & Sons, Inc.; Garst; Hoegemeyer Hybrids, Inc.; Legend Seeds, Inc.; NC+ Hybrids; and Sieben Hybrids. This action substantially reduces the risk that Starlink will create additional problems, but it does not guarantee that no more Starlink contamination problems will occur. The reason is that harvesting was well advanced when the recall decision was made, an additional time lag was needed to implement the plan, and limited cross-pollination of Starlink varieties with corn in neighboring fields may have occurred. A significant part of the Starlink corn likely had already been harvested and co-mingled with other acceptable varieties of corn. As a result, low-level Starlink contamination of U.S. commercial corn supplies is possible until all 2000 corn crop has

[5] Starlink is a registered trademark of Aventis.

been consumed. Starlink was believed to account for 0.5 to 0.6 percent of the U.S. 2000 crop, excluding any contamination from cross pollination of edges of neighboring fields. It is uncertain whether sales of this type of seed were dispersed geographically throughout the corn growing region or were concentrated in certain geographic areas. The Starlink problem will put pressure on the U.S. government to re-examine its approval process for new GMO varieties and crops. The Starlink problems were highly predictable since most U.S. grain elevators and farmers have not attempted to segregate GMO and non-GMO supplies.

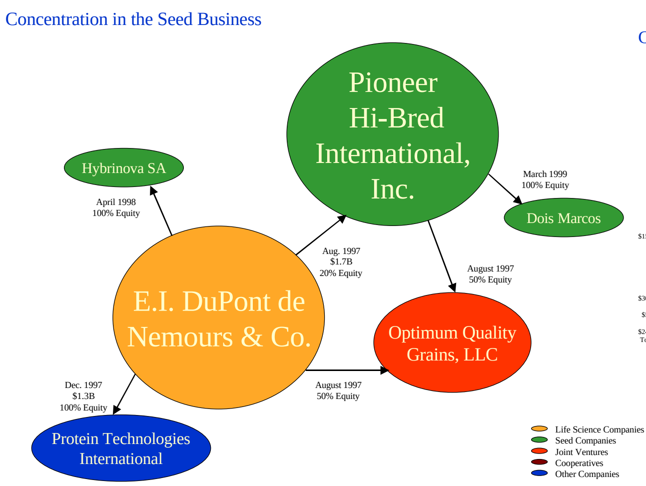
Ownership and control of GMO technology

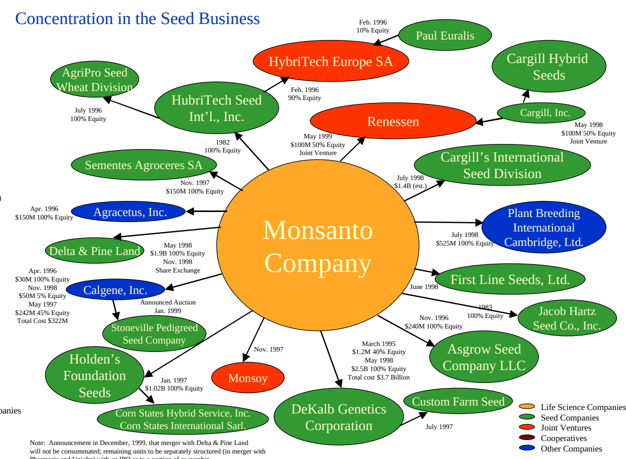
Regarding ownership concentration and control, the figures below (Prepared by Dr. Neil Harl, Charles F. Curtiss Distinguished Professor of Agriculture, Department of Economics, Iowa State University) show interrelatedness of the major multinational firms that own the GMO technology. Large chemical/pharmaceutical firms shown in the figures have purchased major seed companies in the last few years, and have other linkages in the seed, processing, and food processing industries. Six large multinational firms currently own the technology, a sharp decline from the number of firms competing in the seed industry in past years. As this is being written, the seed operations of Novartis are being offered for sale to AstraZeneca, PLC. If the transaction is approved, the number of firms owning the GMO technology would drop to five. Some analysts foresee this number declining further in the future. Concern about the control issue also is related to a gene called the “terminator” gene that prevents GMO seeds from reproducing. If used, this would force peasant farmers in low-income nations to buy new seed every year, rather than continuing the age-old practice of saving seed from the current crop.

Because of extremely low farm incomes in many of these nations, there is concern that such a development would lead to large-scale plantation agriculture, displacing poor farmers and increasing urban poverty problems. Major seed firms have indicated they do not intend to use the “terminator” gene, but there is no assurance this will always be the case.

Environmental concerns

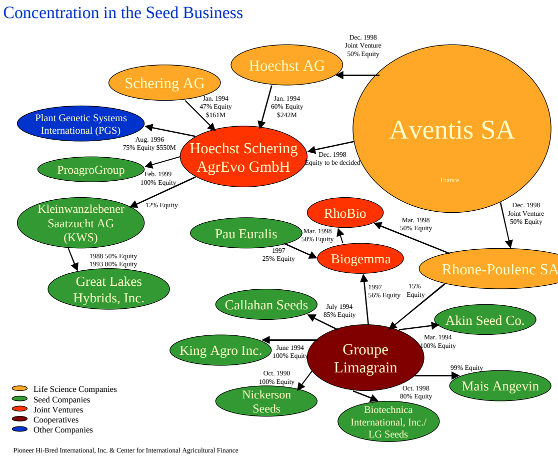
Other reasons for objections to GMO crops come from persons concerned about environmental implications. For many years, U.S. agriculture has focused on “integrated crop management” where pest management practices are used selectively, depending on the need. Many times, for example, chemical control of corn borers is not used because it is not needed. In some years, spraying for corn borers may be done in some but not all fields and only in geographic areas where

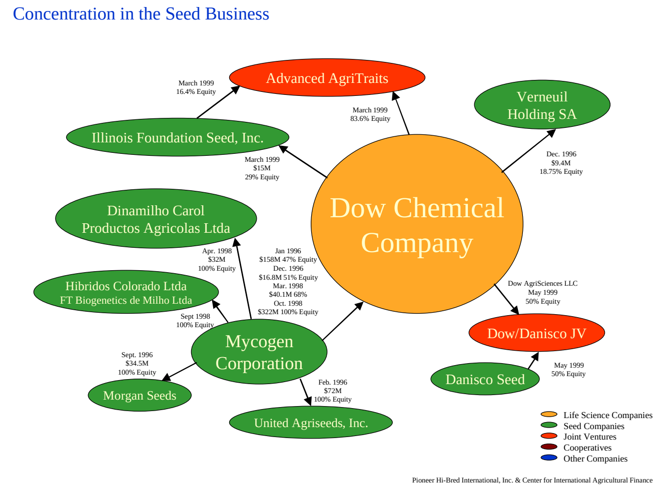




Source: Dr. Neil Harl, Charles F. Curtiss Distinguished Professor of Economics, Iowa State University

insect infestation is severe. The Bt corn, in contrast, is visualized as being used every year, with concern that it might increase the risk that a Bt-resistant borer would develop. Research from Iowa





Source: Dr. Neil Harl, Charles F. Curtiss Distinguished Professor of Economics, Iowa State University

State University and Cornell University showing that pollen from some Bt corn events may increase the mortality of Monarch butterfly larvae also has been related to environmental concerns. Some European researchers indicate that a number of other butterfly species may also be at risk. Other people have expressed the desire for careful research on environmental implications for species that feed on the targeted insects. Concern has been expressed that “super weeds” might develop which are resistant to major herbicides, and that GMO crops might cross with closely related wild species to develop herbicide-resistant wild varieties of the crop. Research in Europe reportedly has shown the ability of herbicide-resistant rapeseed to cross with a wild turnip, producing a herbicide-resistant wild turnip. Similarly, there is concern that the “terminator” gene might cross with native varieties of the crop, causing environmental problems or loss of genetic resources. Accidental cross breeding with wild species such as native varieties of corn in Mexico or soybeans in China and Manchuria also is feared by some to have the potential to reduce the genetic base available for future research. One writer summarized the concern as follows “What is particularly worrisome is that because biological systems reproduce, such genetic pollution cannot be cleaned up like a chemical spill or recalled like a defective automobile. Once the gene is out of the bottle, so to speak, it cannot be put back in” (Andrew Pollack, “We Can Engineer Nature. But Should We?” *New York Times*, February 6, 2000).

An international perspective

Whether or not these concerns are valid is still being debated. Meanwhile, a number of countries have labeling programs or planned labeling programs for grain and oilseeds processed directly for human consumption. Labeling allows consumers to make choices about non-GMO vs. GMO foods, but does not prevent marketing of GMO products. It is a mechanism that consumers can use to register their preferences and how much they are willing to pay for non-GMO products. The European Union has had a labeling program in effect for nearly two years, which resulted in a large number of GMO products being taken off shelves of retail food stores. In some cases, its labeling program applies not only to food stores, but also to restaurants, institutional food providers such as hospitals and elderly care facilities, food caterers, and school lunch programs. Countries with current or planned labeling programs include the following:

- European Union

- Australia
- Japan
- South Korea
- Taiwan
- Malaysia
- Thailand
- New Zealand

This list does not necessarily cover all countries that may be planning labeling programs. For example, Canadians have discussed a possible voluntary labeling program to be implemented by the food industry. Brazil bans GMO crops in its agriculture, although in provinces near Argentina, some GMO soybean seed is smuggled in. China permits production of GMO cotton and tobacco, but not food or feed grains. While labeling programs have focused on crops that are processed directly into human food, vegetable oil has generally been excluded. In the U.S., a 1999 *Time Magazine* survey indicated that 81 percent of U.S. consumers desire labeling of food by genetic origin, and 58 percent said they would avoid buying GMO foods if they were labeled (Time Magazine, January 1999). Harris and *USA Today* Polls also (February and June, 2000) indicated 86 and 79 percent, respectively, of American consumers want a GMO labeling program. Information on these and other similar polls is available at the following web site:
http://www.centerforfoodsafety.org/facts&issues/polls.html
However, resistance to a U.S. labeling program is strong. The U.S. food industry indicates labeling would add substantial extra cost in marketing grain products, and mandatory U.S. labeling by genetic origin is not expected in the foreseeable future. A September 29, 2000 US. Federal District court ruling indicated that the FDA probably does not have a legal basis for requiring labeling of foods by genetic origin, since it does not find GMO crops materially different from conventional products (Philip Brasher, October 4, 2000). Despite a lack of labeling, U.S. consumers can buy non-GMO foods by purchasing “Organically Grown” food, which is produced with no synthetic fertilizer or pesticides and must be non-GMO. In addition, some companies have indicated they will voluntarily shift to using only non-GMO ingredients. Included in this list are FritoLay (a major snack-food manufacturer), Barilla (a major pasta manufacturer), Gerber, and Heinz, as well as several regional firms. In the U.S., the latter two firms have focused non-GMO efforts especially on manufacture of baby food. A major U.S. fast-food chain has indicated it will use non-GMO potatoes in its french fries. One major U.S. chicken producer last year announced plans to shift to use of non-GMO feed, but it is uncertain whether the shift has been made at this time.

The tolerance level on GMO food in the European Union is one percent. For foods containing more than one percent GMO ingredients, a label specifying that ingredients are GMO is required. Foods containing less than 0.1 percent GMO could be labeled as GMO free under proposed rule changes. Australia also is planning a one-percent tolerance level. For Japan and South Korea, we understand that the threshold tolerance level is five percent.

So far, EU GMO labeling does not include livestock feeds. Livestock feed labeling by GMO vs. non-GMO ingredient is being discussed there, with expectations that a decision will be made in early 2001 (Henderson). If required, it would have a substantial impact on the U.S. grain and oilseed sectors. Over 60 percent of two by-product feeds, corn gluten feed and corn gluten meal, produced in U.S. corn processing are exported to the EU. Labeling of feed ingredients by genetic origin would have a serious impact on the U.S. corn processing industry. Another dimension of the issue is that U.S. processors have been unable to assure EU buyers that the corn gluten is produced only from corn varieties officially approved by the EU. EU has not approved some corn events or varieties for import, especially stacked GMO events and certain varieties of Roundup Ready corn. EU halted the GMO approval process in 1999 in response to major consumer concerns.

Corn gluten products are produced in the manufacture of fructose corn sweetener and ethanol, which is used extensively in motor fuels. About twenty percent of the demand for U.S. corn was accounted for by domestic processing in the 1999-00 marketing year. Due to the GMO issue, U.S. corn exports to the EU have fallen from a relatively steady 100 to 120 million bushels annually for many years, to almost nothing in the past two years. The pre-1998 exports resulted from an agreement with the U.S. when Spain and Portugal joined the EU, which provided access to the EU market without import restrictions.

The EU also was a major importer of U.S. soybean meal until the last two years, often the largest or one of the largest importers. EU imports of U.S. soybean meal in the last three years were as follows:

- 1997-98:1.76 million metric tons
- 1998-99: 0.40 mt.
- 1999-00: 0.17 mt.
- 2000-01: At this writing, zero purchases have been made.

EU for decades also had been the largest importer of U.S. soybeans. U.S. soybean exports to the EU fell sharply in 1997-98 and 1998-99, and only partially recovered in 1999-00. It is likely that the GMO issue was a factor in the decline.

On January 29, 2000 in Montreal, Canada, the Global Biosafety Protocol was signed by 130 countries (but not the U.S.) (R. Wisner). This agreement, if ratified, may encourage increased GMO labeling of agricultural products in international commerce. Major features included:

1.Recognition of risks and benefits from biotechnology and the need to protect biological diversity.
2.Establishment of a Biosafety Clearing-House for sharing information about GMOs. Countries must inform the clearing-house within 15 days after their approval of any new GMOs used in food, livestock feed, or processing.
3.Exporters are required to obtain importing-country approval for shipments of GMOs intended for release into the environment, such as seeds.
4.GMOs for food, feed, or processing are exempted from importing country approval, but must be labeled “May Contain GMOs”, and individual countries can decide whether to import the commodities based on scientific risk assessment. Labeling details for the Protocol are to be completed no later than two years after it takes effect.
5. Scientific certainty is not required for importing countries to restrict imports of GMOs. Biological diversity impacts, human health, and socioeconomic factors also may be considered. GMOs for uses such as research are exempted, as are GMOs in transit to another country.
6.GMOs for pharmaceuticals are exempted if they are addressed by other international agreements or organizations.
7.The agreement will be reviewed at least every five years.

To take effect, the agreement must first be ratified by at least 50 nations. Wording in several areas of the treaty will need to be clarified before impacts on global trade can be determined.

How GMOs are created

For hundreds of years, plant breeders have sought genes that are advantageous for pathogen or insect resistance, or for enhancing yield. Conventional plant breeding is in a sense genetic engineering; it can be used to manipulate the genetic makeup of plants toward a desired combination of hereditary traits. To introduce a particular desired gene or set of genes by conventional methods, the two lines are sexually crossed to give first-generation hybrids with a genetic constitution derived from both parents. The hybrids are then grown up and repeatedly back-crossed with one parent until a plant with the desired genetic makeup emerges. This plant will have most of the genes of the one parental variety with a few particular desired characteristics from the other; the process is called introgression. Such breeding process is necessarily slow and usually spans several years, even when a range of genetic and breeding tricks are used to accelerate it. In addition, the transfer of genes from one plant to another is not controllable. Introgression of genes with desired attributes are often coupled with some undesirable genes. Furthermore, such breeding is restricted to sexually compatible species that can only hybridize with each other; thus, it is limited by the natural species barriers to gene exchange.

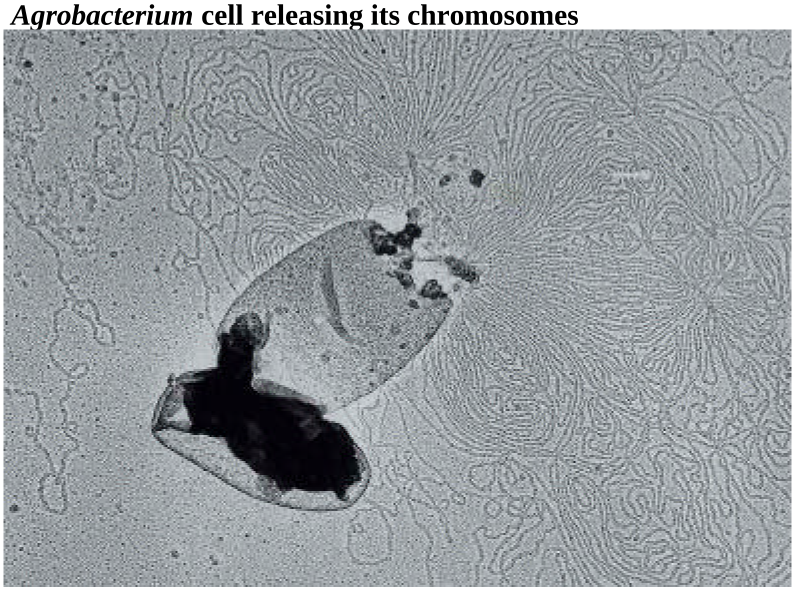
Many agronomically important genes exist outside the species targeted for improvement. For example, cactus can tolerate long periods of dry soil conditions. Some tropical plants are resistant to many pathogens or insects. This has led scientists to contemplate ways of overcoming the biological barriers to gene transfer. Ideally, plant genetists want to introduce single specific genes with defined functions into already useful varieties of plants. That involves two basic steps: first, obtaining the genes in pure form and second, devising ways to insert these genes into plant chromosomes.

Inserting genes into crops

After genes of interest (they may be from plants, bacteria, fungi, viruses, or animals) are characterized for their functions, they are then hooked up with a promoter, a regulatory segment of DNA that activates genes. This promoter-gene combination will be inserted into a vector (small loops of DNA) that will be ready for plant transformation. The vector carrying the promoter-gene segment is called a Construct. There are two major transformation technologies for inserting genetic materials into plants, *Agrobacterium*-mediated transformation – a natural delivery system and biolistic gun-mediated transformation – a physical delivery system (gene gun).

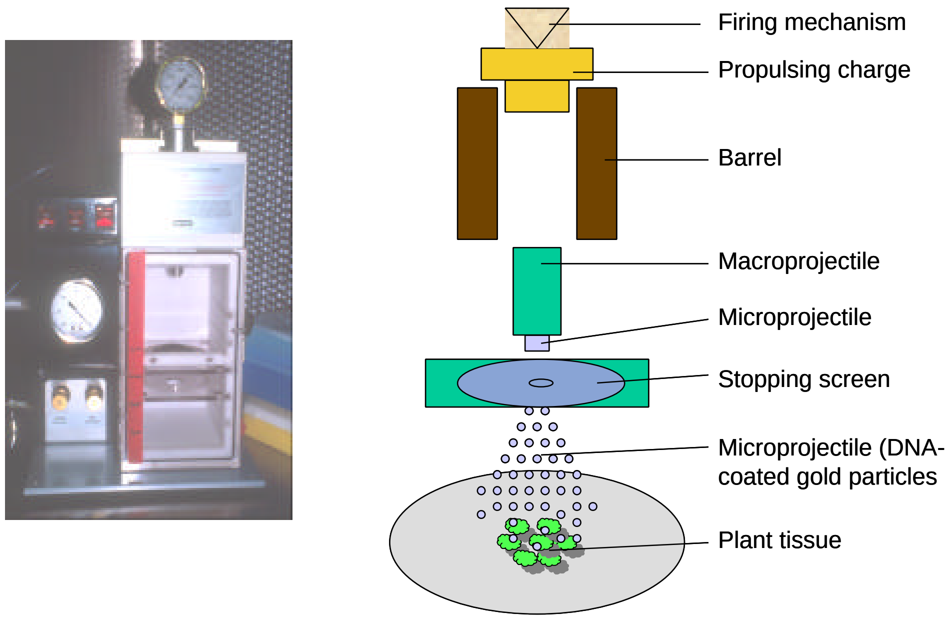
Agrobacterium tumefaciens is a free-living common soil bacterium (Figure 2). Scientists have known since the mid-70s that the bacterium can insert a piece of its genetic segment into a plant

Figure 2. Electron microscopy image of a partially lysed *Agrobacterium* cell releasing its chromosomes



genome and get the plants to express those foreign genes in the form of proteins. In *Agrobacterium* -mediated transformation method, *Agrobacterium* strain carrying the Construct will be incubated

Figure 3. The BiolisticÔ microprojectile gun

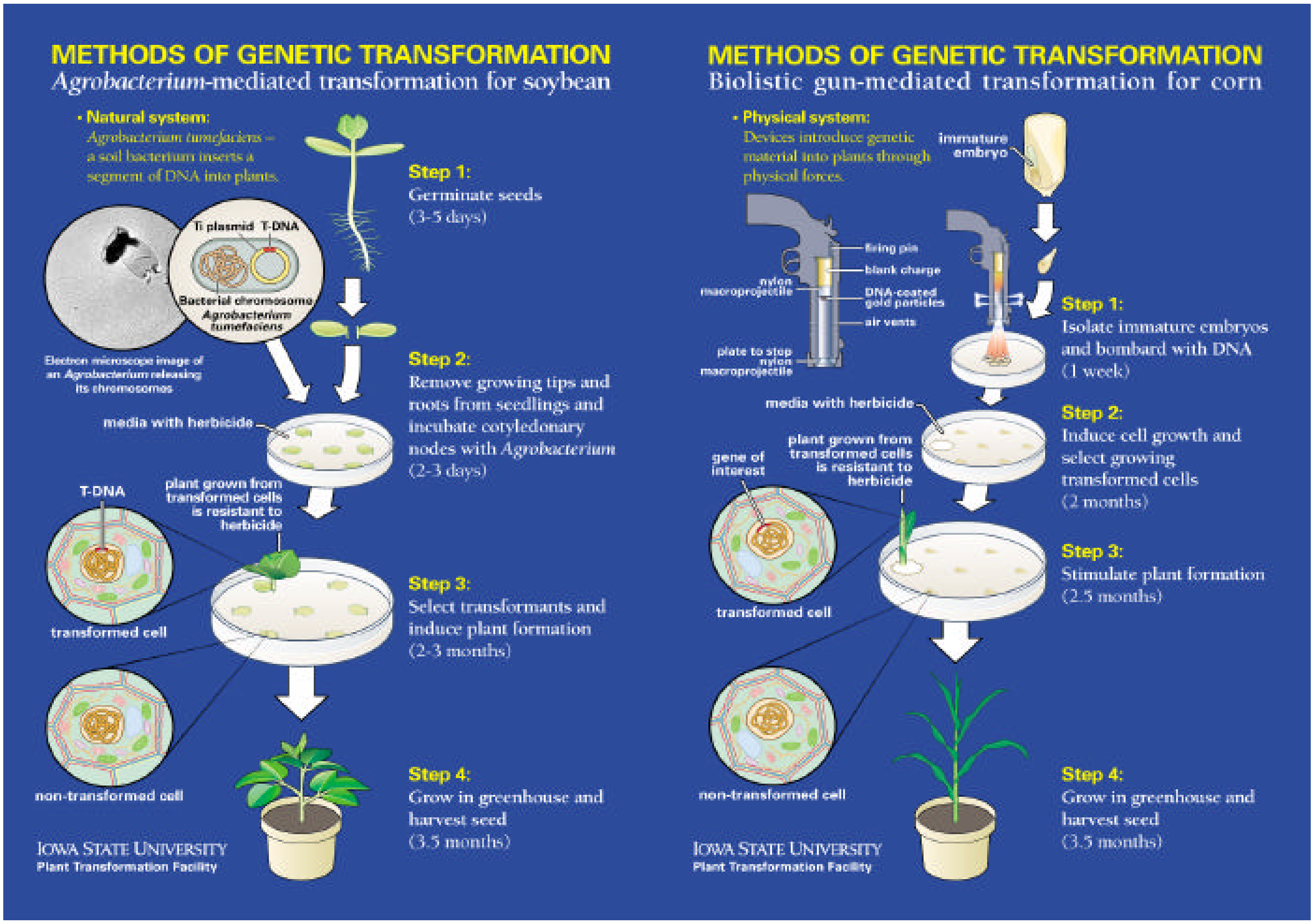


with plant tissue. As they "infect" plant tissue, they also transfer the gene into into the plant cells.

The gene gun was conceived in 1984 (Figure 3b). The purpose of the invention was to introduce DNA into cells by physical means to overcome the biological limitations of *Agrobacterium* – not all plant tissue can be infected by *Agrobacterium* and grown into a whole plant after infection. In this biolistic (<u>bio</u>logic bal<u>listic</u>) process, construct DNA is coated on the surface of gold particles (0.6 – 1 µm in size). The DNA-coated gold particles (microprojectiles) are accelerated by helium gas to speeds sufficient for the penetration of plant cell walls and membranes.

After delivering genes into plant cells, the challenge is to effectively identify the few transformed cells among millions of untransformed cells. One device used for selection is that the vector carrying the gene of interest (GOI) also carries a selectable marker gene such as an antibiotic resistant gene or herbicide resistant gene (genes capable of detoxifying antibiotics or herbicides). Cells that are transformed with GOI usually also carry those selectable markers. When the cells are grown on plant nutrition medium containing antibiotics or herbicide, non-transformed cells will die while transformed cells will survive and thrive under such conditions (Figure 4).

Figure4. Methods of Genetic Transformation.



<u>Genetic modifications for soybeans, corn, other crops, and where the new genes were found</u>

The first generation of transgenic crops involves so-called input traits enhancement. For instance, corn plants have been improved with DNA from *Bacillus thuringiensis* (Bt), a bacterium producing a protein (Bt-toxin) that kills the European corn borer and other pests. Herbicide tolerant soybean and corn plants are other examples of input trait improvement. Bacterial genes encoding enzymes that detoxify active ingredients of herbicides were inserted into crops. Other improved input traits crops include virus-resistant tobacco, tomato, and squash. Most of these genes were isolated from bacteria, fungi or virus, some were from plants. There are also limited numbers of commercial transgenic crops with enhanced output traits. The first released to market was Flavr Savr® tomato produced by Calgene (now Monsanto) in 1994. In Flavr Savr tomato, one of the genes determining fruit cell wall structure during the ripening process was genetically altered. This resulted in a tomato with prolonged shelf life and enhanced flavor for ripened fruits. However, this tomato had other handling disadvantages and was later removed from the market.

<u>How GMO research has been financed</u>

Funding for GMO research has come from both the U.S. government and private-sector. Funding agencies providing financing for this type of research include:

- National Science Foundation (NSF)

- Department of Agriculture (USDA)
- Department of Energy (DOE)
- National Institute of Health (NIH).
- Seed industry
- Agrichemical companies.
- Rockefeller Foundation
- Ford Foundation
- McKnight Foundation
- Iowa Corn Promotion Board
- National Corn Growers Association
- Iowa Soybean Promotion Board
- United Soybean Board

Promising future transgenic developments

The study of genes involves the rapidly developing field of genomics, which refers to determining the DNA sequence and identifying the location and function of all the genes in an organism. It appears that many traits are conserved between species, ie, the same gene confers the same trait in different species. Thus, a gene for drought tolerance in cactus may confer drought tolerance if it is transferred and expressed in corn or wheat.

Photo 2. Producers like the simplicity of Roundup Ready soybeans, which produce relatively weed-free fields.

Increased knowledge through the plant genomics allows researchers to further improve crop production. In oilseed rape, certain genes have been found to cause "pod shatter", a problem that can cause farmers to lose as much as half of the oil-bearing rape eeds. By eliminating pod-shattering genes from these plants using genetic engineering, farmers can double their yields or plant half as much land for their crops. Increased production, in turn, lowers market prices and benefits consumers, but puts financial pressure on farmers because of an inelastic demand for agricultural products.

The second generation of agricultural biotechnology products involves output traits. These products are expected to provide even more dramatic benefits worldwide. Researchers have already made great strides in genetically engineered rice that contains more vitamin A precursor and accumulates more iron than conventional varieties, thus having the potential to prevent infections, blindness, and anemia in developing countries. Bananas are being genetically engineered to contain vaccines against diseases such as hepatitis B, cholera, and diarrhea – with the potential for creating edible vaccines that are cheaper and easier to deliver to children around the world. Vitamin E is the most important fat-soluble antioxidant that must be obtained from the human diet. Soybean and corn seed oil contain potential vitamin E precursors with low activities. A gene that can convert the low activity precursors to the highest activity vitamin E compound has been isolated from plants. By genetic transformation, researchers will be able to produce soybean, corn, or canola seed oil with enhanced vitamin E in the future.

Similar work is being carried out to create more nutritious and disease-preventing livestock feed. Corn is expected to be developed that has enhanced nutritional properties and corn-based edible vaccines for livestock diseases, allow producers to feed hogs and poultry fewer additives and medications, and reduce the risk of large herd disease outbreaks.

It is believed that existing foodstuffs could be reengineered to remove undesirable components such as the allergenic protein in nuts or enzymes in soybean that causes odor in manure when the seed is used for feed. Corn and soybean are also considered as future renewable resources for industrial products. Conventional breeding programs in conjunction with chemical mutagenesis has been used to produce and select corn and soybean varieties with enhanced compositions such as specific starch or oil types or increased contents. With the dramatic increases in knowledge of plant genomics, researchers will be able to engineer the plant metabolic pathway or regulate gene expression cascades more effectively. The term,"designer crops," refers to those crops with certain compositions and functional properties that will meet needs for different markets. For example, cornstarch with improved gelatinization temperature for the film-producing industry, healthier cooking oils, biodegradable plastic, or cheaper glucose production from corn for ethanol as future fuel for automobiles are possible products.

Percentage of U.S. corn and soybean area planted to GMO crops in 2000

The primary source of this information is the U.S. Department of Agriculture, National Agricultural Statistical Service (NASS), June 30, 2000 *Planted Acreage* report. NASS is responsible for estimating a wide range of agricultural data including crop and livestock production, crop area and yields, agricultural prices, and other specific economic information related to the crop sector. In June of each year, it makes a large-scale survey of farmers across the nation to determine the land area planted to specific crops. In 1999, 57 percent of the soybean crop and 35 percent of the corn crop were estimated to be GMO varieties. Its June 2000 survey indicated that for the major corn and soybean producing states, 54 percent of the U.S. soybean area was planted to GMO varieties. For corn, the estimated total area planted with GMO seed was 25 percent. Reduced plantings reflected farmer concern about the market acceptance of GMO crops.

Corn GMO varieties include "Roundup Ready" (RR) and Liberty Link herbicide resistant varieties, Bt corn, and stacked varieties which contain both Bt and herbicide-resistant genes. The respective percentages of these three corn types were: 6, 18 and 1 percent. Table 1 shows the estimated percentages of the crop area that were GMO by major producing states. ***Note that GMO varieties are used much more extensively in the Corn Belt states west of the Mississippi river, than in the eastern and northern parts of the Midwest.*** GMO use in Ohio, Michigan, and Illinois, as well as in the southern U.S. and North Dakota is well below that in Iowa, Nebraska, Kansas, and Missouri. Processors seeking out non-GMO supplies can use the table as a guide to the areas where these supplies are most readily available. Few GMO varieties were available for planting in 2000 in extreme northern regions such as North Dakota and northern Minnesota . Cautions are necessary when attempting to convert these data to percentages of the total U.S. supplies that are non-GMO. First, in most areas of the U.S., the grain industry made no attempt to segregate corn and soybeans by genetic origin in the 1999-00 and 2000-01 marketing years. The segregation that was done tended to be on farms, for direct movement from farms to barges for export. Much of the supply that remains from the last marketing year and from the 2000 crop is a mixture of GMO and non-GMO varieties, and must be considered GMO corn and soybeans for marketing purposes. Secondly, in the case of corn, GMO varieties in adjacent fields can cause cross-pollination that might contaminate at least the edges of non-GMO fields. Cross pollination, however, is not a problem with soybeans. Because of these considerations, there is no accurate way of estimating the percentages of U.S. corn and soybean supplies that are truly non-GMO for marketing purposes.

Table 1. Percent of U.S. Corn and Soybean Area Planted with GMO Varieties, 2000, by states.

	Corn Percent GMO	*Soybeans Percent GMO*
Iowa	30	63
Kansas	33	66
Missouri	28	62
Nebraska	34	72
South Dakota	48	68
Indiana	11	63
Illinois	17	44
Michigan	12	50
Minnesota	37	50
North Dakota	Not Available	22
Ohio	9	48
Arkansas*	Not Available	43
Mississippi*	Not Available	48
U.S.	25	54

*Very minor corn producing state

U.S. GMO Approval Procedures

Three government agencies in the U.S. are involved in approving new types of GMO seeds: the Food and Drug Administration (FDA), the U.S. Department of Agriculture, and the Environmental Protection Agency (EPA). The FDA is responsible for food safety issues, and the EPA is responsible for environmental impacts such as effects on desirable insects and species that feed on them. In general, companies that develop the new seeds are required to perform specific tests, and to bring the data from these tests to the relevant government agencies for review and approval. The agencies themselves do not do the testing. For FDA approval, the company's results from feeding trials with laboratory animals, medical evaluation of the animals and comparisons with results from feeding non-GMO products to identical control groups of animals are an important part of the data the firms are required to present. Questions raised about this process by some consumer groups were noted at the start of this report.

Innovation in U.S. Agriculture

The introduction of transgenic crops has perhaps created more controversy than any technology since the introduction of hybrid seed corn in the late 1920s. A percentage of the producers, call them risk-takers or innovators, will readily buy into new technologies hoping to get a head start on the usage of the new technology.[6] A much larger percentage will usually adopt a "wait and see" attitude. They are interested in the new technology, but are less willing to take the risk and invest in it. They wait to see if the technology proves itself before investing.

The speed at which a new technology is accepted depends on the perceptions the potential users have of its potential benefits for themselves. Benefits may come through increased returns (e.g., increased yields, reduced production costs), labor savings (e.g., easy to use, reduction in number of operations), environmental savings (e.g., reduction in pesticide usage), or other similar savings. If the risks seem large and the benefits small, adoption will be very slow, if at all. Conversely, if the risks seem small and the benefits great, adoption will be rapid.

[6] There also will exist a percentage, also risk-takers, who will oppose a new technology. This opposition may, and usually does, continue long after there has been widespread acceptance of the new technology.

Why U.S. farmers have rapidly adopted transgenic crops

With a new technology, producers are naturally curious about the potential benefits. The idea of producing a plant that is able to ward off major insect pests or allows the use of non-selective weed control has tremendous appeal among crop producers. For that reason, innovators embraced this

Photo 3. Postemergence herbicide application.

new technology and were eager to introduce it into their production systems. The benefits appeared great and risks minimal, therefore adoption has been rapid, especially for Roundup Ready soybeans.

Importance in Weed Control

Agricultural losses from weeds are large (both in crop losses and dollars spent on control). Weeds deprive crop plants of moisture and nutrients and shade the crop, hindering normal growth and development. They contaminate harvested grain with seeds that may have detrimental effects on humans or animals and, in some cases, may cause total loss of the crop. Agriculturalists have battled weeds for centuries, initially with mechanical and cultural means (e.g., hand cultivation, cover crops, fire) and more recently with chemical means (herbicides).

Herbicides can be classified as *selective* or *nonselective* in terms of the vegetation they control. A *selective* herbicide would kill certain types of plants but not exert any effect on others. An example would be a preemergence grass herbicide applied on soybeans [*Glycine max*. (L.) Merr.] The grass herbicide would be applied immediately after the crop was seeded, controlling grassy weeds but having no effect on other weeds or desired crops. A *nonselective* herbicide is one that is toxic to all plants. *Nonselective* herbicides are used where removal of all vegetative material is desired or as a directed, or spot, treatment to eliminate certain weeds within a crop stand.

Conventional weed control systems incorporate mechanical, cultural, and chemical control strategies. These strategies have been in use for decades and still are important techniques for weed control. Generally, some form of preplant tillage is used to eliminate early emerging weeds. This is followed by some form of cultivation (after crop emergence) to eliminate later emerging weeds. In addition, herbicides are used to further reduce weed pressures at both pre- and postemergence crop stages.[7] Early planting, plant densities, row spacings, and crop selection are examples of cultural control strategies. In all cases, timing is critical (small weeds are much easier to control than large weeds). Weather delays may result in poor control of weeds in some cases, and major losses to the crop.

[7] Conventional herbicide programs involve a pre-emergence grass herbicide followed by one or more post-emergence herbicide applications for grass and broadleaf weed control. On occasion, tank mix applications, consisting of two or more herbicides mixed together, may be applied to reduce the total number of applications while providing adequate control of both grasses and broadleaf weeds.

The ability of some plants to resist or tolerate the effects of certain herbicides has led to the development of specialized, herbicide-resistant crop varieties. Initially, through natural selection, these specialized plants were identified and selected for propagation.[8] Resulting varieties then are capable of resisting the effects of an herbicide that is toxic to other varieties of the same crop species. This process allowed farmers to use some very broad-spectrum herbicides (in terms of the number of weed species they control) and improved weed control dramatically.

Transgenics, or the insertion of herbicide resistance genes from one plant species into the desired crop species, is the latest technology for rendering plants resistant to harm from herbicides. Producers who want simplicity in weed control strategies will find it in these crop varieties. Essentially all weed species can be controlled with a single, nonselective, herbicide without harming the crop. Roundup herbicide is the main type used in this way, explaining why new herbicide-resistant varieties are called "Roundup Ready" soybeans or corn. With this technology, timing of application also becomes less critical because the broad-spectrum herbicides have toxic effects on weeds of all sizes.

Roundup Ready technology has revolutionized weed control, but must be regarded as one of many options available for corn and soybeans. Weed scientists stress the importance of a varied and integrated approach to controlling weeds, involving more than a single control method. With

Photo 4. Misapplication of a nonselective herbicide (Roundup®, Monsanto) onto a non-transgenic soybean crop. Photo courtesy of Dr. Keith Whigham, Department of Agronomy, Iowa State University.

the possibility of certain weeds developing a resistance to the particular herbicide, proper management and usage of these specialized crop varieties is very important. In addition, producers who use these varieties need to keep accurate records showing where they were planted on their farms (if other, non-transgenic varieties are planted also). Accidental application of the companion herbicide onto sensitive, non-transgenic plants can have devastating results. Herbicide drift onto

[8] Seeds of a particular variety are planted and then treated with a particular herbicide. Any surviving plants are grown to maturity and seeds collected. This process would be repeated until a population is produced that is resistant to the herbicide.

Photo 5. Herbicide drift damage on a sensitive crop (corn). The soybean crop on the right is genetically engineered to resist the toxic effects of the nonselective herbicide.

sensitive crops and other plants is another risk that must be dealt with when using this technology.

<u>Importance in insect control</u>

Insects have plagued crops and crop producers since the beginnings of agricultural production. Insect pests damage crops in numerous ways, from the loss of plant tissue during growth to the destruction of grain during harvest and storage. Worldwide, crop losses from insect pests amount to millions of tons annually. As with weeds, control measures have included mechanical, cultural, and chemical, and more recently the use of transgenic crops.

Of the conventional insect control methods (mechanical, cultural, and chemical), chemical controls have been the most successful by far. Chemical insect control has been practiced for centuries, but it was only after World War II that the arsenal of chemical controls began to expand and develop into what it is today. Mechanical and cultural control methods are still used, but not as extensively as chemical controls.

Photo 6. Internal stalk damage caused by European corn borer. Photo courtesy of Dr. Marlin Rice, Department of Entomology, Iowa State University.

Expanded use of chemical insect controls brought increased scrutiny of effects on humans, livestock, wildlife, and the environment. Insecticides generally were applied over large areas, indiscriminately killing almost all insects they came in contact with, harmful or beneficial. To manage crop pests effectively and economically, yet remain sensitive to environmental and human concerns, the concept of "integrated pest management" (IPM) was developed. This concept, as the name implies, promoted an integrated approach to pest control. Rather than relying heavily on a single control method (i.e., pesticides), utilization of a combination of chemical, mechanical, biological, and cultural controls was suggested. Field scouting for pest levels also was encouraged, enabling the estimation of "economic thresholds" for specific pests. Economic thresholds identify the potential amount of crop loss, based on pest infestation level, and were a guide to determining when control measures should be used.

Even with IPM strategies, producers and the general public were concerned about the use of chemical insect controls. Certain biological, or microbial, controls showed promise in controlling specific insect species while being extremely safe to humans and the environment. One such microbial control is *Bacillus thuringiensis*, or Bt, a soil-borne bacterium that is toxic to specific insects, primarily those of the order Lepidoptera (butterflies and moths). It works by producing a toxic substance (a crystal-like protein or Cry protein) in the gut of the insect. Once eaten, the insect's own digestive enzymes activate the toxic form of the protein. Its ability to control only the target insect pests and its effectiveness have made it a very popular insecticide, especially for horticultural crops. [9]

Through genetic engineering, scientists have been able to isolate the gene that controls the expression of the Bt toxin and to insert it into the genetic code of certain crop plants. Of considerable importance in Iowa and other parts of the U.S. Corn Belt, is the development of Bt corn hybrids that resist the devastating effects of the European corn borer [*Ostrinia nubilalis* (Hübner)]. The European corn borer (ECB) causes millions of bushels of damage each year, much of it unseen to the producer because the damage is done internally within the plant, disrupting the flow of water and carbohydrates to the developing ear and grain. It is estimated that one ECB larvae per corn plant will reduce yields by approximately 5%.[10]

Plant geneticists created Bt corn by inserting the specific DNA from the Bt organism into the corn plant's DNA as described in an earlier section. Genes from the Bt organism are first modified to improve the expression capabilities in the corn plant. Then a promoter is attached to signal where and how much of the Cry protein the plant will produce. Some promoters will limit the expression of the Cry protein to specific parts of the plant (e.g., leaves or green tissue only) while others will enable the production of the protein throughout the plant.

Compared with current IPM options, Bt corn can dramatically improve ECB control. Chemical pesticides are only capable of controlling 50-90% of the ECB larvae in a field. On the other hand, Bt corn hybrids can provide up to 99% control of early season ECB larvae (whorl stage corn). Control of late season ECB larvae will vary among hybrids, depending on the expression level of the protein. Besides providing excellent control of ECB and reducing the concerns of chemical pesticide usage, Bt corn offers several other advantages to farmers:

- The yield protection is guaranteed; there is no need for scouting or calculating economic thresholds for treatment.
- There is documented evidence that Bt corn hybrids can help reduce ear and stalk rots.
- There is no direct impact on beneficial insects or wildlife (except as we noted earlier, there is some concern about impacts on Monarch butterflies).
- There is evidence of limited control of corn earworm, armyworm, and fall armyworm in addition to ECB.

Limitations in usage of Bt corn include:

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[9] Various formulations of Bt have been used for over 30 years in non-transgenic applications. Several strains of Bt involving over 60 different Cry proteins have been identified. Consequently, the list of insects controlled by some of these toxins has been expanded to include certain beetles, flies, and mosquitoes.

[10] In Iowa, a preliminary 2000 corn crop production estimate was 47.2 million tonnes (1.86 billion bushels). A 5% loss to ECB would equal 2.4 million tonnes (93 million bushels). Computing aggregate dollar value of farmer losses is complex. At a market price of $70.90 per tonne (approximately $1.80 per bushel), that amounts to a loss of $167 million for Iowa alone in 2000. The higher price of corn resulting from a reduced supply would reduce the loss by about $19 million, still leaving a net loss of $148 million. However, the higher price for the remaining 1.77 billion bushels of production would be more than offsetting, leaving a net gain in aggregate value of the corn crop of $17 million from supply-control caused by the insects. Actual losses vary from year to year, depending on insect population levels. ECB tends to be a less severe problem in the Eastern Corn Belt than in Iowa and other Western Corn Belt areas.

- ECB infestation levels vary from year to year and cannot be predicted. Therefore, the need for Bt corn cannot be predicted.
- An economic return on the investment is not guaranteed. If ECB populations are low, the premium price for Bt corn seed (additional $17-25 per hectare) may not be recovered.
- It offers no control of certain other damaging insects. This may change in the future as different Bt genes are inserted into corn hybrids.

With these features, Bt corn hybrids have become quite popular among U.S. western Corn Belt farmers. In only four years since its introduction, the percentage of corn acres planted to Bt hybrids in the U.S. has gone from 0 to approximately 19%.[11] There are concerns, however, regarding the possibility of resistant ECB developing and that excessive use of this technology will ultimately result in its demise. For this reason, it is recommended that no more than 80% of a producer's acres be planted to Bt corn hybrids. This leaves a "refuge" where ECB can reproduce and reduce the chances that resistant biotypes will develop.

Challenges not yet addressed with transgenic varieties

Biotechnology opens up many new possibilities for crop production and pest management. So far, it has generated improvements to the shelf life of vegetables, specific insect resistance, herbicide resistance, and improved protein, oil, and other nutritional characteristics of grains and oilseeds, to mention a few. New strains of Bt continue to be identified and inserted into plants resulting in protection from a variety of insects. One example (although not approved for sale at this writing) is a type of corn resistant to corn rootworm (*Diabrotica* species).

Along with the types of crops discussed above, plant geneticists also have had success in transferring multiple genes. These "stacked" trait hybrids are capable of, for instance, resistance to both herbicides and insects. Trait stacking may lead to the development of crop plants that resist most major insect pests as well as possessing a resistance to herbicide that will simplify weed control as well. For the year 2000, farmers planted an estimated one percent of the corn crop with "stacked" varieties that resist Roundup and the ECB[12].

Increased Farm Size and Transgenic Crops

The long-term trend toward fewer and larger farms in the U.S. is another factor encouraging the use of Roundup Ready soybeans. Or perhaps this and other types of technology are encouraging larger farms. Since 1958 in Iowa, the number of farms has declined by 48%, while the average farm size has increased by 80% (Table 1). As the average farm size increases, producers look for strategies to reduce labor requirements per acre.

Table 2. Iowa farms: number, average size, and total land in farms.

Year	Number of Farms	Average Farm Size (hectares)	Total Land in Farms (million hectares)
1958	189,000	75	14.1
1968	149,000	94	13.9
1978	128,000	108	13.8

[11] The first year of introduction was 1996. There were, however, a limited number of hybrids approved for sale at planting time in 1996. Therefore, the first year of significant acreage planted to Bt hybrids was 1997. Data on Bt corn use in 2000 are from U.S. Department of Agriculture, National Agricultural Statistics Service, *Crop Acreage* (Washington, D.C.), June 30, 2000.

[12] *Ibid.*

1988	107,000	127	13.6
1998	99,000	135	13.4

Source: Iowa Agricultural Statistics.

University yield test results with Transgenic Corn and Soybeans

Selecting the best hybrid or variety to plant is perhaps one of the most important decisions a producer can make. Therefore, it's important that producers spend time evaluating the performance of numerous varieties that would be adaptable to his/her farm. Several sources for hybrid/variety performance information are available, including university and seed company performance trials, local performance trials (sometimes sponsored by a local farmers' cooperative or county Extension office), and neighbor comparisons. Producers look to university variety performance trials to provide accurate, unbiased information on variety performances in their area. Iowa, like other states, is divided into "districts" based on variety adaptability (climatic and soil conditions). Generally, at least three sites per district are used in the trials. Individual seed companies are allowed to decide whether to participate in the trial, and what varieties they want to enter in a particular district. An entry fee (per hybrid, per district) is charged to cover costs of performing and reporting the test. Once harvest is complete, the results are published and distributed to the producers (both in print and electronic forms) a soon as possible. Data reported includes yield, grain moisture at harvest, amount of lodging, specific disease ratings, and specific quality ratings (percentage protein, starch, or oil, for instance). Hybrid or variety performance is reported for up to three years (if the company chooses to enter it in the trial for up to three years). This enables producers to gauge a variety's performance over time, also.

Transgenic varieties may be entered in the same performance trials as non-transgenic varieties. With herbicide resistant varieties, however, plot design and randomization may influence the herbicide program that can be used. Either a conventional, selective-type herbicide must be used on all varieties (including the transgenic), or the sensitive, non-transgenic varieties must be protected from the nonselective herbicide suited for use on the transgenic variety. The latter method is perhaps the preferred method (although more laborious) because the producer is able to evaluate the variety as it would be grown in his or her production system.

Limitations of variety performance trials

A criticism of university variety performance trials is that they may not be the best representation of the variety's performance on all farms. These trials are conducted on a limited number of farms across a large geographic area, and each plot is relatively small compared to the average field (approximately 0.002 hectare in size). Despite these limitations, this system is a good way of evaluating the performance of a large number of hybrids or varieties, since major influences on yields are carefully controlled. Because they are conducted by uninterested third parties, the results are viewed with a higher degree of credibility.

Yield comparison of transgenic vs. non-transgenic varieties

An initial concern for many farmers who considered using transgenic varieties was an expectation that inserting these specialized traits would be accompanied by lower yield potential. Yield test results for the first year confirmed such a tendency. However, with more time and work on plant breeding, variety performance trials now show the transgenic varieties to be strongly competitive in yield, while also possessing specialized traits to assist in pest management.

How transgenic seed is sold to farmers

Until recently, corn and soybean seed companies traditionally have used farmers exclusively as their sales agents. These sales agents generally are individuals that possess some knowledge of agronomy, sales and marketing, and are familiar with the hybrids and/or varieties that the company is offering for sale. The sales agent services a particular geographic area, developing a good working relationship with the clients.

Each seed company decides which hybrids or varieties it will offer for sale each year. Sales projections are used to determine whether a variety is offered for sale, and how much is offered each year. The sales projections incorporate the previous year's sales, performance of the variety, and expected demand in the current year.

<u>Cost of transgenic vs. non-transgenic seed</u>

The price charged must cover the costs of production and allow for some profit. Transgenic crops, developed through the use of biotechnology, demand a premium price to cover the costs of the biotechnology processes. Establishing prices to charge producers for these specialized crops has been challenging for seed companies.

Initially, the seed is priced at a baseline price (per unit), assuming a slightly higher cost for the specialized seed. Certain discounts are then applied and deducted from the total cost of the seed order. Discounts may be available for such items as large volume orders, early delivery of seed, and early purchase of seed, and apply to both conventional and transgenic types of seed. Initially, a "technology fee" also was assessed to the purchase price (per unit) of the transgenic-type varieties, to cover additional costs in the development of the transgenic varieties. Technology fees were not accepted favorably by many producers, who felt the extra cost in the baseline price should cover the added technology expense. As a result, the technology fee was dropped in 2000. Each seed company now sets its own price and pays a fee to the biotechnology developer, if the developer was outside the company. Seed costs for transgenic varieties have been approximately 30-35% higher than for non-transgenic varieties.

<u>Transgenic seed purchasing agreements</u>

Because the gene technologies are protected under U.S. patent law, the biotechnology companies generally have issued "technology agreements" with the purchase of any transgenic seed. These agreements define the proper use of the transgenic products and specify the legal rights of the biotechnology company should the producer violate the terms of the contract. They are signed by the producer at the time of the seed purchase. The agreements generally will apply to all transgenic crops developed by the particular biotechnology company and are considered *evergreen*. The term, *evergreen*, means that the producer only needs to sign an agreement once. It will be effective for all transgenic crops from that company which the farmer grows in the future; any changes or updates to the agreement will be provided by the biotechnology company. Violation of any of the terms of the agreement will terminate the agreement immediately and may prohibit the producer from obtaining another agreement in the future.

<u>Marketing of Non-GMO crops</u>

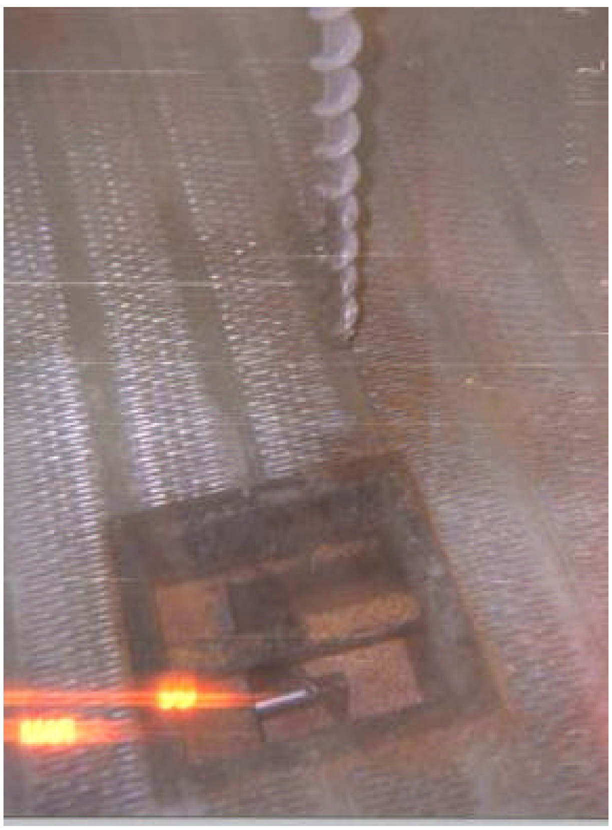
Marketing is a process that begins on the farm where the crop is produced. To be marketed as non-GMO corn or soybeans, the farmer must avoid contamination with GMO supplies. If both GMO and non-GMO crops are produced on the same farm, that begins with careful cleaning of planting

equipment to be sure that no GMO seed is present, and requires careful records indicating the brand and variety of seed planted in each field. In the case of corn, which has risk of cross-pollination, the non-GMO varieties should be planted a safe distance from any GMO fields to minimize such risk. There is not widespread agreement on what is a :safe" distance. Crop certification agencies have generally used 203 meters for this distance if a corn crop is being grown in the entire 203 meters. However, the "safe distance" may vary with weather conditions and whether or not there is an open field or low-growing crop over part of that distance. Cross-pollination risk is not a problem with soybeans, thus making the segregation process somewhat easier. Where GMO and non-GMO crops are grown on the farm, careful attention to cleaning combines, bins, augers, and conveyor systems is essential. When harvesting equipment is used for other specialty crops such as seed soybeans, edible dry beans, or other edible food crops that require segregation, one way of cleaning the combine (harvesting machine) is to harvest

Photo 7. Farm Storage Bins.

enough of the specialty product through the machine to fill its receiving tank. The tank then is emptied and that first portion of the harvest is marketed it as a non-specialty grain. The remainder of the crop is then harvested and marketed as a specialty product. Another alternative is to open the clean-out hatches of the combine's conveyor systems, run the machine to get as much GMO product out as possible, and then use a large vacuum cleaner to complete the cleaning job. Where only non-GMO corn or soybeans are grown, this step would not be necessary.

Photo 8. Farm Storage Bin With Unloading Conveyor, Perforated Floor, and Stirator Auger.



The photos above show a typical farm storage bin, with a perforated floor for aeration and artificial drying. Underneath the floor is a conveyor system that requires extra time and expense to clean if it has been used for a GMO crop the previous year. If the bin is used year after year for non-GMO grain, there is no added cost for this part of the handling process. If the farmer does not have enough non-GMO soybeans or corn to completely fill a bin, the ownership cost per bushel or ton of grain increases because these costs are spread over less than the maximum possible volume.

At least one U.S. firm provides a service that works with farmers to test and certify that corn and/or soybeans are non-GMO varieties, and helps provide paperwork for certification from planting to marketing.

The following photos show some Iowa grain elevators, the typical first stage in the grain and soybean marketing system after the crop leaves the farm. Many elevators are older and have been gradually modified and expanded over time. Some of these can be more effectively used to segregate grain by genetic origin than others. They may have separate truck and wagon unloading pits and conveyor systems that can be designated for use with GMO crops, while the rest of the facilities are used for conventional

Photo 9. Examples of Iowa Grain Elevators That Could Segregate by Genetic Origin.

varieties. Also, these elevators tend to have smaller storage bins that can accommodate smaller

Photo 10. Another Elevator with Some Grain Segregation Potential, but Probably Not at Harvest.

volumes of specialty grains. This flexibility, however, comes with a slower handling speed and higher cost than in newer elevators. Most newer elevators (shown in other photos below) have large storage bins, often with 12,000 to 15,000 metric tons of storage capacity in each bin. Many are designed with one central conveyor system that is used for all of the grain coming into the elevator. Segregation would require shutting down the facility, cleaning the dump pits and conveyors, and then receiving only non-GMO grain for a period of time. At harvest time, this would be extremely difficult to do because waiting time during this season is very expensive for farmers (note the harvest scene at one elevator). An alternative marketing channel that is being used in Corn Belt areas along the Mississippi, Illinois, and Ohio rivers is to move the corn directly from the farm to river barges which are then moved downstream directly to port elevators.

Photo 11. An Elevator with Less Potential for Segregation.

U.S. port elevator facilities vary somewhat but several of them have the ability to receive and load non-GMO soybeans and corn handled in this way. Here again, handling smaller volumes tends to somewhat increase the cost, along with additional testing and record-keeping that is involved. In northern areas where GMO varieties have not been widely available, such as North Dakota and northern

Minnesota, marketing of non-GMO crops has been greatly simplified.

Costs of marketing non-GMO soybeans and corn vary considerably by region and type of marketing facilities used, and by volume handled. ***When only a few small shipments of identity preserved non-GMO grain or soybeans are run through an elevator, all costs of cleaning and special handling are spread over a small volume of grain. However, if the volume is large enough that an elevator can designate one entire section of its facilities to non-GMO grain for an entire season, the increased costs would be minimal.*** A 1991-93 survey of Iowa elevators showed that half of those sampled estimated they could segregate supplies of specialty grains for $1.10 per metric ton (Hurburgh, et al.). However, volumes required to attain these cost levels were not indicated. Outbound segregation costs were not estimated, but large-volume shipments lower the railroad shipping cost by $7 to $8 per metric ton. It appears that ways can be found to ship several identity-preserved carloads in a 100-car train that is predominantly GMO grain without sacrificing freight cost advantages, but this has not been extensively tested. Additional segregation costs would be occurred at port elevators. In a 1998 University of Illinois survey, segregation costs of handling specialty grains also were estimated at $1.10 per metric ton (Hill, et al.). Other related costs added another $1.10 per metric ton and included risk-management, transportation, and testing. These elevators paid an average price premium of about $6.50 per metric ton to farmers, and specialty grains accounted for nine percent of their total volume of grain and soybean business. A University of Missouri study taking account of lost income from less than optimum use of storage facilities and coordination costs estimated total costs for specialty crop segregation at approximately $6.30 to $10.60 per metric ton (Maltsbarger and Kalaitzandonakes). The results were based on three different sizes and types of elevators in Missouri and Illinois.

In late September or early October 2000, the American Corn Growers Foundation (ACGF) surveyed 1,107 grain elevators in nine U.S. Corn Belt states to determine the extent of segregation in U.S. grain supplies. Through the survey, it was found that 30.5 percent of the elevators were requiring or suggesting segregation of grain as it entered their elevators. The survey also indicated that 41.6 percent either required or suggested that farmers segregate on the farm before delivering to the elevator. The ACGF indicated that in total, 72.1 percent of the elevators were either requiring or suggesting that the grain be segregated. Twenty two percent reportedly were paying price premiums for non-GMO corn. The range of premiums reported was from 10 to 25 cents per bushel.

In Brazil, where a significant part of the European Union's non-GMO soybeans are purchased, there are two types of identity-preserved non-GMO marketing channels. One is referred to as "Soft GMO", and the other as "Hard GMO". The "Soft GMO" soybeans are those shipped from port elevators whose trade areas are known to be non-GMO soybean areas, basically north of Sao Paulo. The "Hard GMO" soybeans have papers certifying the origin and shipping details, and documenting that they are non-GMO soybeans. Because of larger volumes being handled and lack of need for segregation in those areas where the entire crop is non-GMO, Brazil's costs of handling non-GMO soybeans probably are considerably lower than in the U.S.

Summary and Conclusions

Transgenetic modification of crops is a highly controversial issue. The first-fruits of the new technology are now available, and have been engineered for producer rather than consumer benefits. Proponents believe this procedure will and must play a key role in providing plentiful and increasingly nutritious food for future generations in a world where population has doubled in less than four decades. Others who urge a more cautious approach, believing that more testing is needed to determine the long-term safety of these new food products, with procedures that insure absence of conflicts of interest in the testing. Areas where more testing is urged also include environmental impacts and potential impacts on the genetic base represented by wild varieties of related non-GMO crops.

The amount of information available to the public about GMO issues varies from country to country. In the European Union, information and publicity about the products has been much more widely available than in the U.S. Some of it no doubt lacks scientific accuracy, and recent problems in food safety there have increased consumer concern about food-related issues. From a consumer standpoint, a strong case can be made for labeling of food products by genetic origin, thus allowing consumers to make purchasing choices and show how much value they are willing to place on non-genetically modified products. Land O' Lakes (LOL), a major U.S. dairy processing cooperative, chose to deal with the BST issue in milk production in this way, offering consumers a product labeled as non-BST milk. The result was that 18 percent of LOL's volume of fluid milk sales have been accounted for by this product (Runge and Jackson). Segregation issues in milk production have some resemblance to those in soybeans and grain. If the size of the market for non-GMO products is small, their prices necessarily will be significantly higher than for GMO-based foods in a world where the majority of the crop production is GMO or where GMOs are considered to be the base level for marketing purposes. Added costs are the result of expenses involved in keeping non-GMO products separated in the production and marketing system. If the volume of demand is large, these costs would be quite low, but if non-GMOs represent only a small niche market, costs for non-GMO soybeans and corn could be quite high.

If current visions of the long-run potential for the biotechnology and GMO revolution materialize, it will be essential that farmers and the U.S. and international grain marketing system develop mechanisms for moving away from large-volume bulk commodity marketing. A system will need to be developed that allows efficient segregation of as many as six or eight (or possibly more) different types of corn and soybeans. Today's GMO segregation issues are only the first stresses on the system in its transition away from bulk grain to value-added products. If the industry fails to make the transition and to develop efficient methods for segregation, the future of transgenetics may be restricted to those products whose primary benefits are focused on the farmer, and the challenge will be to convince consumers that the new products reflect their best long-run interests.

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