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# Genetically Modified Organisms: An Overview

## An introduction to Genetically Modified Organisms (GMOs) including information on development, current research, and potential uses.

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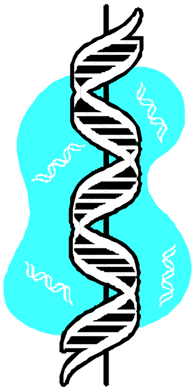

Recently, we have been inundated with information about new products developed from “Genetically Modified Organisms” or GMOs. This new class of products ranges from pharmaceuticals to varieties of pest resistant corn, soybean, cotton and other crops. The first product that resulted from a GMO was marketed in 1982 when the US Food and Drug Administration approved human insulin produced by genetically altered bacteria. The bacteria were modified by insertion of a mammalian gene into the bacterial genome to produce insulin. The insertion of the insulin gene, and the portion of DNA which regulates production of insulin, enabled the bacterial cells to produce commercial quantities of insulin in culture. The insulin was then chemically extracted from the culture and purified for human use. This event, more than 28 years ago, marked the dawn of a new age of commercialization of GMO products. Today, virtually all insulin, as well as many vaccines are produced by genetically modified bacteria.

The research that led to recombinant DNA technology began in the early 1970s. The ability to excise DNA from one organism and insert it in a functional manner into another organism became known as

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# GMO's

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"Recombinant DNA Technology" or "Genetic Engineering". This technology led to the creation of new combinations of DNA molecules that were not previously found together in nature. Today, recombinant DNA technology has reached the stage where scientists can take a segment of DNA from nearly any organism, including plants, animals, bacteria, or viruses, and introduce it into another species. An organism that has been modified is commonly referred to as a genetically-modified organism (GMO), living modified organism (LMO) or transgenic organism. The offspring of a cross involving a GMO parent is also termed GMO if it carries the inserted or recombinant DNA. Not all GMOs involve the use of cross-species genetic exchange. Recombinant DNA technology can also be used to amplify the expression of a gene. Amplification of genes is important when a species is capable of producing a gene product, but the product is produced in insufficient quantities. This technique is often used to improve disease resistance or nutritional quality of a plant.

Recombinant DNA technology came about because traditional plant breeding techniques that involved hybridization between parents of the same species frequently, but not always, are limited to genetic exchange within a crop species. Hybridization has been used since crops were first domesticated to increase yield, improve pest resistance and environmental stress tolerance, and enhance food quality. This activity has provided us with an abundance of food, however, in an increasing world population the demand to continue increasing food production is necessary. Recombinant DNA technology provides us with new tools that will enable us to continue improving crop yield, economic return, pest resistance, stress tolerance, and nutritional quality of our food, as well as contribute to the preservation and improvement of our environment.

Recombinant DNA technology has several advantages over conventional breeding methods. First of all, the exchange of DNA with recombinant DNA technology is far more precise than conventional plant breeding because only a single or a few specific genes are incorporated into a recipient plant. Consequently, there is no need to eliminate undesirable genetic combinations in segregating populations, as with conventional hybridization. Secondly, desirable traits that are not available in the species can be incorporated into a crop. For example, genes that confer cold tolerance in fish can be cloned and inserted into plants to enable crops to withstand freezing temperatures or be grown in cold climates. Likewise, genes for salt tolerance, heat tolerance and other abiotic stresses can be incorporated into crop plants to develop resistance or tolerance that is not present in a crop species. These accomplishments may enable us to produce food and protect land that is not presently suitable for crop production.

Improved food quality and nutrition are also important goals of transgenic crop technology. Health experts estimate that 180 million

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Technical Editor

Reviewers for this issue were Dr. Jim Quick, Dr. Scott Haley, and Dr. Duane Johnson, all of Department of Soil and Crop Sciences at Colorado State University. We appreciate the time and effort they spent on our behalf.

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# GMO's

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children worldwide suffer from deficiency in vitamin A, and 2 million deaths are attributed to this deficiency annually. Vitamin A deficiencies also predispose children to diseases such as measles and diarrhea. Recently, scientists in Europe have genetically engineered a "Golden rice" that produces three times the amount of vitamin A as conventional rice. Eventually the scientists plan to develop rice that contains the entire daily requirement of vitamin A in one serving. Golden rice should help save the lives of millions of children worldwide. Scientists are also working on introducing genes that increase the content of iron in rice. If the level of available iron in rice were increased three-fold, more than 2 billion people would be affected and millions of lives could be saved. For these reasons, biotechnology holds the key to providing both the caloric and nutritional needs for an ever expanding world population.

Even though biotechnology has the potential to provide increased food and nutrition to the world population, not everyone has welcomed this technology with open arms. Economic, social, and moral issues surrounding the propagation and marketing of GM crops or food products has become a focal point for some environmental and religious groups. Many European Community (EC) countries have boycotted the production or importation of GM crop products. These economic sanctions have created a concern among international corporations that export crop products from the US to Europe. Some international buyers have indicated that they will not purchase GM crop products because they cannot separate GM from conventional crop commodities and/ or do not want to jeopardize losing clients that fear GM products. Some countries, such as Thailand, use molecular genetic technology to determine if a crop commodity was produced from GM varieties to prevent them from being imported. Other commodity buyers, such as Cargill, have publicly released statements that they intend to purchase GM crop commodities. In Colorado, most corn buyers are not concerned about GM corn because it is used for feed in confined animal feedlots where human consumption is not an issue. For a more detailed discussion of issues related to transgenic crops, read Transgenic Crops: Risks And Concerns in this issue of the newsletter.

At the center of the controversy surrounding the use of GMO products are the ethical questions regarding the transfer of DNA across organisms. The critics of GM products are, in general, well nourished and have not experienced the threat of famine on a personal level. As a global society, we need to think broader than our own personal needs, and embrace technology that can provide a more balanced and complete diet to people worldwide, especially in regions that are presently undernourished. An excellent source of information about GMOs can be obtained from a paper issued by the Council for Agricultural Technology (CAST) in 1999. That paper is available on the Internet at http://www.cast-science.org/castpubs.htm.

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## meet. . .

Dr. Abdel Berrada is a Research Scientist at Colorado State University Southwestern Colorado Research Center. His research program focuses on soil, crop, and water management under dryland and irrigated conditions. He has also been evaluating alternative crops such as chickpeas for adaptability to southwestern Colorado. Berrada joined CSU in 1993. He has been responsible for planning and coordinating agronomic research at the center, and managed the center for six years.

# Transgenic Crop Production And Regulation

## Creating a transgenic crop is an involved process, and current regulations of the process involve a number of agencies.

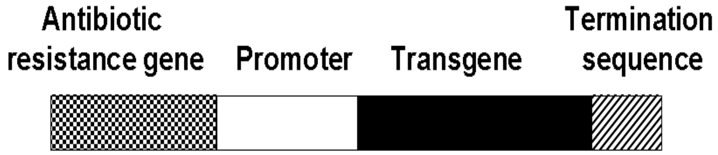
The ability to produce transgenic crop varieties has been one of the major breakthroughs of agricultural biotechnology. Since the first transgenic plant was developed in the early 1980's, the technology has steadily become more efficient and versatile, though transgenic crop development remains a time- and resource-intensive process. This article summarizes the current state of transgenic technology.

Excising genes of agronomic importance is currently the most limiting step in the transgenic process. Public and private research programs are investing heavily in new technologies to rapidly sequence and determine functions of genes of important crop species. These efforts should result in identification of many genes potentially useful for producing transgenic varieties. Once identified, these genes can be located and excised from an organism.

In order for a gene to be correctly expressed (i.e., translated into a protein product), the DNA sequence of the gene must be flanked with a promoter and a termination sequence (Fig. 1). The promoter is the on-off switch that controls when and where in the plant the gene will be expressed. To date, most promoters in transgenic cultivars have been "constitutive", i.e., causing gene expression in all tissues throughout the life cycle of the plant. The termination sequence signals to the cellular machinery that the end of the gene sequence has been reached.

Addition of a selectable marker is the next step. Incorporation and expression of transgenes in plant cells are rare events, occurring in just a few percent of the targeted tissues or cells. To permit the efficient detection of tissues with successfully integrated transgenes, a selectable marker gene is added to the transgene construct (Fig. 1). These genes encode proteins that provide resistance to agents that are normally toxic to plants, such as antibiotics or herbicides. As explained below, only plant cells that have integrated the selectable marker gene will survive when grown on a medium containing the appropriate antibiotic or herbicide.

**Figure 1. Simplified representation of component parts of a constructed transgene.**



Insertion of the transgene into plant tissues (transformation) is accomplished in one of two principal ways, and the goal is to introduce the foreign gene into plant tissues and obtain stable integration in the plant's chromosomes. Typically, immature embryos are the target tissues. The Agrobacterium method utilizes the remarkable soil-dwelling bacterium *Agrobacterium tumefaciens*, which has the ability to infect plant cells with a piece of its DNA. When the bacterial DNA is integrated into a plant chromosome, it effectively hijacks the plant's cellular machinery and uses it to ensure the proliferation of the bacterial population. Many gardeners and orchard owners are unfortunately familiar with *A. tumefaciens*, because it causes crown gall diseases in many ornamental and fruit plants. The DNA in an *A. tumefaciens* cell is contained in the bacterial chromosome as well as in another structure known as a Ti (tumor-inducing)

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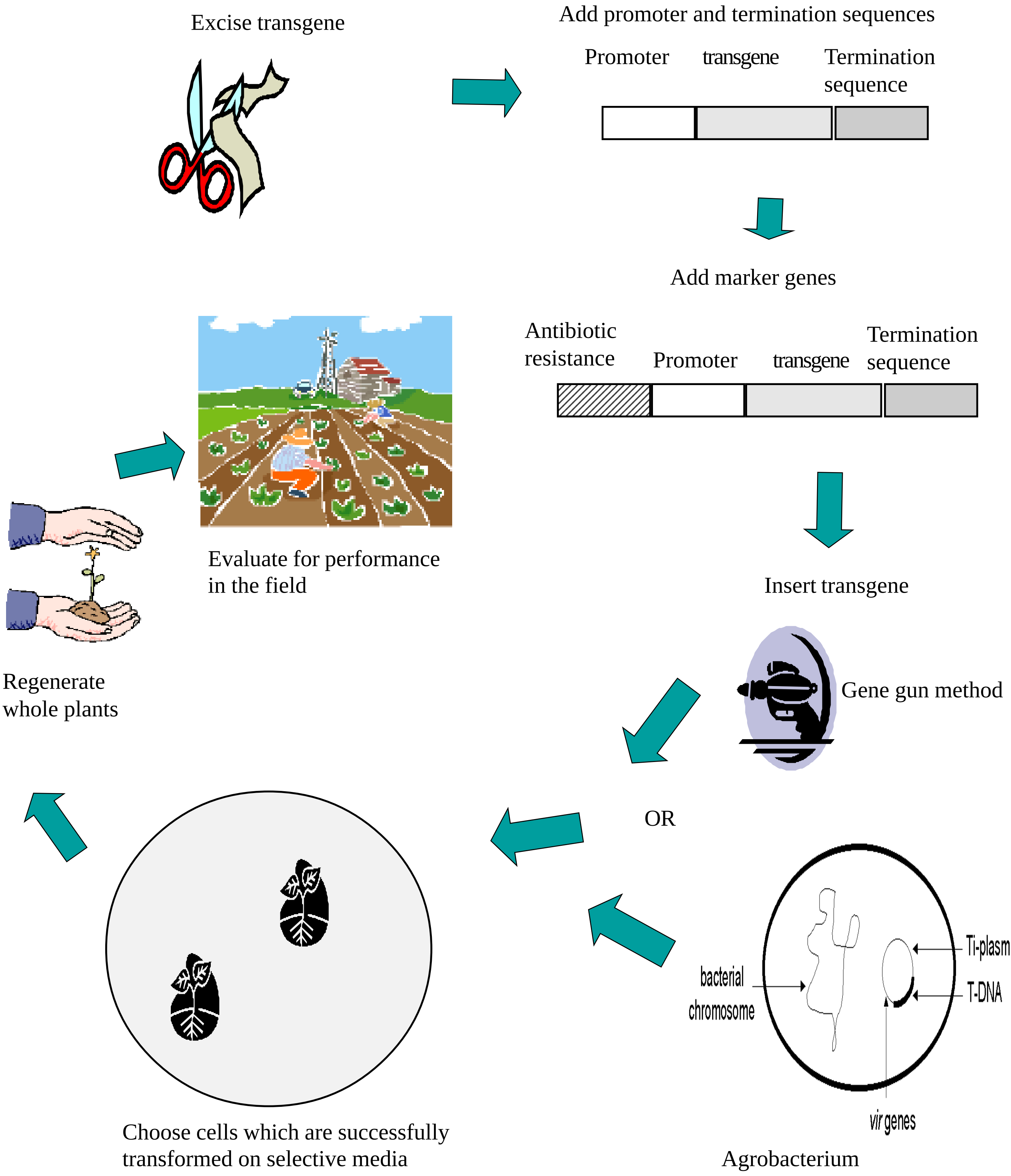
# Producing Transgenic Plants



Excise transgene

Add promoter and termination sequences

Promoter transgene Termination sequence

Add marker genes

Antibiotic resistance Promoter transgene Termination sequence

Insert transgene

Gene gun method

OR

Agrobacterium

Choose cells which are successfully transformed on selective media

Regenerate whole plants

Evaluate for performance in the field

# Production

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plasmid. The Ti plasmid contains (1) a stretch of DNA termed T-DNA that is transferred to the plant cell in the infection process, and (2) a series of *vir* (virulence) genes that control the infection process.

To harness *A. tumefaciens* as a transgene vector, scientists have removed the tumor-inducing section of T-DNA, while retaining the T-DNA border regions and the *vir* genes. The transgene is inserted between the T-DNA border regions, where it is transferred to the plant cell and becomes integrated into the plant's chromosomes. Transformation via Agrobacterium has been successfully practiced in dicots (broadleaf plants) for many years, but only recently has it been effective in monocots (grasses and their relatives).

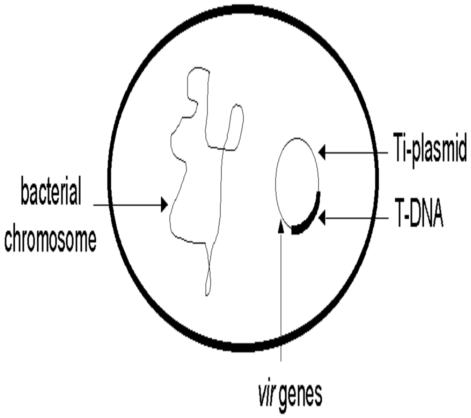

**Figure 2. Diagram of an *Agrobacterium tumefaciens* cell.**

Another common method is to shoot DNA fragments into plant cells with a "Gene gun". With this method, tiny particles of gold or tungsten are coated with the transgene and propelled at high speed into target tissues. As disruptive as this seems, it does result in the stable integration of the transgene into target cells in a small percentage of cases. The gene gun method, also known as microprojectile bombardment or biolistics, has been especially useful in transforming monocot species like corn and rice.

Selection of successfully transformed tissues occurs next. Following the gene insertion process, plant tissues are transferred to a selective medium containing an antibiotic or herbicide, depending on which selectable marker was used. Only plants expressing the selectable marker gene will survive (Fig. 3), and it is assumed that these plants will also possess the transgene of interest. Thus, subsequent steps in the process use only these surviving plants.

Whole plants with the transgene are obtained by growing the immature embryos under controlled environmental conditions in a series of media containing nutrients and hormones, a process known as tissue culture. Once whole plants are regenerated and set seed, evaluation of the progeny begins. This regeneration step has been a stumbling block in producing transgenic plants in many species, but most crops can now be regenerated.

Intrinsic to the production of transgenic plants is an extensive evaluation process to verify whether the inserted gene has been stably incorporated without detrimental effects to other plant functions, product quality, or to the intended agroecosystem. Evaluation includes attention to:

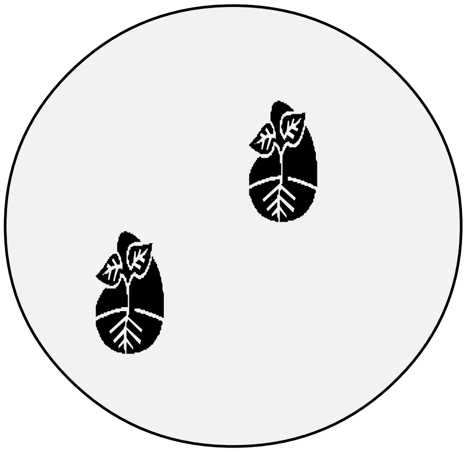

**Figure 3. When grown in petri plates with selective media, only plant tissues that have successfully integrated the transgene construct will survive.**

- Activity of the introduced gene
- Effects of the inserted DNA on plant growth, yield, and quality
- Environmental effects
- Food or feed safety

**U.S. regulatory process**

Transgenic crops are regulated at every stage in their development, from research planning through field testing and food and environmental safety evaluations. The major U.S. regulatory agencies for transgenic crops are described below.

Most research institutions have an *Institutional Biosafety Committee*

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# Production

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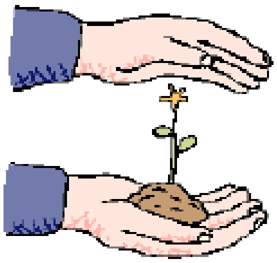
(IBC), which monitors potentially hazardous biological research and ensures compliance with biological safety procedures. At Colorado State University, for example, researchers must notify the IBC if planning to work with recombinant DNA in any form, and appropriate biosafety procedures are mandated according to the nature of the risks involved. Construction of a plant biotechnology greenhouse, including strict containment features for initial testing of transgenic plants, has recently been completed at CSU.



*Animal and Plant Health Inspection Service* (APHIS) of USDA administers the Federal Plant Pest Act and assumes that genetically modified organisms are pests unless proven otherwise. APHIS regulates the transportation and field testing of transgenic plants. During field testing, APHIS requires that researchers undertake procedures to minimize spread of the transgene and keep it out of the food supply, for example by detasseling corn to prevent pollen shed. To commercialize a transgenic plant, the researcher petitions APHIS for "non-regulated" status. This requires extensive data on the introduced gene construct, effects on plant biology, and effects on the ecosystem, including spread of the gene to other crops or wild relatives.

The *Food and Drug Administration* (FDA) has authority under the Federal Food, Drug, and Cosmetics Act to determine the safety of foods or food ingredients. FDA consults with the plant developer and reviews safety and nutritional data. If the introduced gene is from a known allergenic source, then the transgenic food must be assessed for allergenicity. For example, if a gene from peanut (which causes allergic reactions in some people) were introduced into soybean, the FDA would require extensive allergenicity tests. Additional investigation may be required for transgenic crops if they involve known toxicants, altered nutrient levels, new substances, or some types of antibiotic resistance marker genes.

*Environmental Protection Agency's* (EPA) authority to regulate transgenics is based on two laws, the Federal Insecticide, Fungicide, and Rodenticide Act, and the Federal Food, Drug, and Cosmetics Act. To implement its oversight of transgenic crops, EPA (1) reviews environmental effects of the proposed technology, including effects on beneficial organisms; (2) may require a "resistance management plan" to slow down development of resistance in the target pest; (3) sets tolerance levels for pesticide residues; (4) regulates new uses of existing pesticides, such as use of herbicides together with herbicide-resistant transgenics.

Due to recent regulatory developments, U.S. federal regulation of transgenic crops and foods derived from them will probably become more stringent. Two high-level committees have been formed to review health, environmental, social, and economic concerns of transgenic crops. They are the (1) National Academy of Sciences Committee on Genetically Modified Crops Containing Pesticide Genes, and (2) USDA Advisory Committee on Agricultural Biotechnology. Reports from these committees are expected by late 2000.

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# Transgenic Crops: Risks and Concerns

## Despite potential social issues, agriculture can't afford to ignore transgenic crop technology.

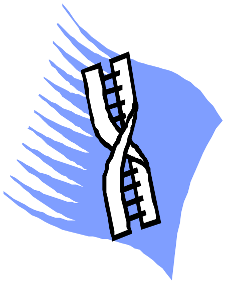
Demonstrators at the recent World Trade Organization talks in Seattle took to the streets to denounce transgenic crops as dangerous "Frankenfoods" which threaten the health of humans and the ecosystem. Anti-transgenic demonstrators dressed as giant corn plants devouring monarch butterflies were seen on newscasts throughout North America this January. In Britain last summer, experimental plots of transgenic corn and canola were uprooted and destroyed by anti-transgenic crop campaigners, and attacks on facilities conducting research on transgenic crops are occurring with increasing frequency in the U.S. People are clearly worried and frightened by this new technology. What are the main concerns associated with transgenic crops? And what are the real risks?

**Ethical issues**

Are transgenic crops unethical? Some of the opposition to this technology is based on the conviction that artificially inserting the genes of one species into another is immoral and unethical. Britain's Prince Charles expressed this view recently in a widely publicized announcement that "Genetic engineering is best left to God." In this context, however, it is worth remembering that even non-transgenic crops are not "natural": for thousands of years farmers have been genetically modifying the plants and animals they grow for food and fiber. Human selection for features such as faster growth, larger seeds or sweeter fruits has dramatically changed domesticated plant species compared to their wild relatives, and artificial cross-pollination has been used for hundreds of years to increase yields or combine desirable characters from different parents in the offspring. Transgenic technology enables useful genes to be brought together in one plant from a wider range of living sources, not just from within the crop species or from closely related plants. This powerful tool expands the possibilities open to plant breeders, but they are continuing to do what humans have done for a very long time: modify the genetic makeup of crops to make them more useful and productive. Prince Charles is not known to live exclusively on a diet of wild seeds, nuts and berries!

**Health-related issues**

Are transgenic crops a health hazard? A frequently voiced concern is that human consumption of foods obtained from transgenic crops might be a health risk. An experiment carried out in Scotland, where rats fed for ten days on transgenic potatoes containing a lectin gene from the snowdrop plant appeared to develop internal organ damage, is often cited in support of this claim, although this particular study has been widely criticized by other scientists as being too small-scale and inconclusive.



Some transgenes may pose human health risks when consumed: for example, a project to insert a brazil nut protein gene into soybean was halted when early tests showed that people allergic to nuts reacted to the modified soy products. This

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# Concerns

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demonstrates the need to consider potential health effects in new transgenic crops, but it also shows that proper testing can identify risks. Labeling transgenic food products containing potential allergens may be necessary. It should be remembered, however, that many "natural" food plants contain metabolic products toxic to humans (for example, raw green potatoes contain dangerous alkaloids, rhubarb leaves contain poisonous levels of oxalic acid, and some individuals are seriously allergic to fava beans or strawberries). Although almost half the U.S. soybean crop and a quarter of U.S. corn, now consists of transgenic varieties, which means that we have all been eating transgenic food products for some time, there is as yet no single case reported of anyone suffering health effects as a result.

Another area of concern is the possibility that antibiotic resistance genes used as markers in transgenic crops may be transferred to pathogenic bacteria, especially as routine use of antibiotics as feed additives in the livestock industry has been widely blamed for the increased incidence of antibiotic resistance in infectious strains of gut bacteria such as *Salmonella* and *E. coli*. The chain of events that would transfer an antibiotic resistance gene from a transgenic plant to a pathogenic bacterium is quite unlikely, and there is no evidence that it occurs. However, in response to concerns about this remote possibility scientists are starting to use alternative marker genes in transgenic plants, such as the GFP gene which makes the plant fluoresce when placed under UV light.

**Environmental issues**

Are transgenic crops a threat to the environment? Many opponents of transgenic technology are concerned that the widespread planting of transgenic crops will have unintended impacts on other organisms in the environment. Bt corn, which contains a bacterial gene enabling the plants to manufacture a substance toxic to the larvae of butterflies and moths but harmless to other organisms, has been a target of criticism since a laboratory study published in 1999 suggested that Bt corn pollen dusted onto milkweed leaves was harmful to monarch butterfly larvae feeding on them. Clearly the environmental impacts of crops containing transgenes must be monitored and assessed. In the case of Bt corn, follow-up studies have shown that pollen from Bt corn rarely reaches toxic levels on milkweed in the field even when monarch butterfly larvae are feeding on plants adjacent to a corn field. Planting Bt corn also greatly reduces or eliminates the need for spraying with pesticides which are far more damaging to non-target insect populations.

A more serious environmental impact of the widespread planting of Bt crops is the development of resistance in pest populations as a result of widespread exposure to Bt. This is of special concern to organic growers who have for many years relied on Bt sprays as an important tool in pest management. Regulations now in place require the planting of "refuge" sections of non-Bt corn or cotton in Bt fields. These refuges enable non-resistant insects to survive and reproduce, thus reducing the opportunity for the pest population to develop high levels of Bt resistance. Research is also under way to target the expression of insecticidal transgenes such as the Bt gene to specific tissues in the plant. This means that the Bt toxin would only be present, for example, in tissues where pest species feed, such as leaves or stalks, not in the pollen.

Growers of non-transgenic varieties have also expressed concern about contamination of their crops with

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# Concerns

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pollen containing transgenes from nearby fields. More information is needed about the extent of this risk for different crops. A recently completed study at the University of Maine found that cross-pollination of conventional corn by transgenic corn grown in an adjacent plot was 1% at a distance of 100 feet and declined to zero at a distance of 1000 feet. These results suggest that for corn it will be quite feasible to prevent the transfer of transgenes to non-transgenic varieties by following recommended isolation distances, just as is currently done to maintain purity with conventional varieties. Prevention of pollen transfer with crops that are highly self-pollinating (e.g. wheat, soybeans) should prove to be even more feasible.

The widespread planting of transgenic crops containing a herbicide-resistance gene, such as Roundup Ready varieties which can be sprayed with glyphosate, has led to concerns that the transgene will be spread by cross-pollination to weed species to create herbicide-resistant “superweeds”. This is a real threat where transgenic crops grow alongside closely related weed species, such as wild mustards in canola or jointed goatgrass in wheat. Gene movement from crop to weed through pollen transfer has been demonstrated for both of these crops. This kind of ecological risk needs to be assessed before the release of new transgenic crop species, and there is also a need for careful monitoring for the spread of transgenes into wild species. Proposals to reduce the risk of creating transgenic “superweeds” include the use of tandem constructs which link herbicide-resistance genes to other genes which are harmless to the crop but damaging to a weed, such as genes which affect seed dormancy or prevent flowering in the next generation. Thus if a weed did acquire a herbicide-resistance gene through cross-pollination with a transgenic crop, its offspring would not survive to spread the herbicide resistance through the weed population.

**Biodiversity issues**

Do transgenic crops reduce biodiversity? Yet another criticism aimed at transgenic crops is that they will replace traditional crop varieties, especially in developing countries, causing loss of diversity and genetic erosion. This risk is real, but not restricted to transgenic crops. Farmers around the world have adopted new commercial varieties in the past and they will continue to do so as long as it is to their advantage. The answer here would appear to be better germplasm conservation strategies for traditional varieties in danger of being lost, rather than opposition to transgenic crops themselves.

Overall, there are some identifiable risks associated with transgenic crops, such as the possibility of the spread of herbicide resistance genes into weed populations or the development of high levels of Bt resistance among insect pests. These risks need to be acknowledged and minimized with appropriate management strategies, but they do not justify rejecting the entire technology. The next generation of transgenics includes crops such as rice with enhanced levels of iron and vitamin A, bananas containing cholera vaccine, and oilseeds which can replace petroleum products as renewable resources for industrial processes. Can we really afford to pass them up?

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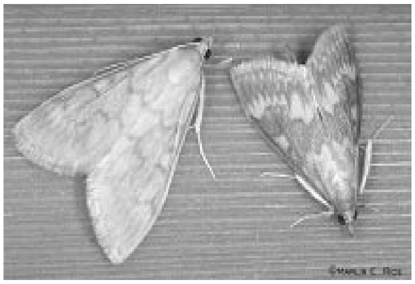
# Bt Corn In Colorado

## Use of Bt events to combat insects are governed by EPA guidelines, including refuge requirements.


corn borer larva

Bt refers to common soil-inhabiting bacteria called Bacillus *thuringiensis*, and to insecticide products made from the bacteria. Some strains of Bt kill insects by producing toxins called insecticidal crystal proteins or delta endotoxins. Endotoxins are stomach poisons that have to be eaten by the insect to be effective and mortality may take several days. Insecticides consisting of dead Bt and endotoxins have been sold for many years but endotoxins break down quickly when exposed to UV light. In Bt corn however, endoxtin is effectively protected from UV light.

A single bacterial gene controls production of endotoxin, which can be put in corn, and produce endotoxins that will be toxic to insects. The amount of endotoxins produced by a given Bt hybrid, and the plant tissues that produce endotoxins, are controlled by the insertion location of the Bt gene in the corn genome (event) and the promoter inserted with the gene that governs when and where endotoxin is produced. Different seed companies use different events and promoters, so the insecticidal properties of their Bt hybrids are different. See Table 1.


corn borer adult

The Bt trait should not affect hybrid yield performance but events and promoters affect how much and what kind of endotoxin is produced in each tissue. It is better to compare insect control by event. For example, corn borer control will be similar in hybrids containing Mon810 and better than in hybrids containing 176.

Bt corn will control corn borers without affecting predators and other beneficial insects. However, if pollen from Bt corn falls on a milkweed plant while caterpillars of the Monarch butterfly are feeding, there will be some mortality. The threat to Monarch butterflies in Colorado is quite low since this insect is rare in our state. Conventional corn borer sprays are also a great risk to many nontarget insects. Bt corn does not cause more human allergic response than conventional corn.

**Table 1. Different Bt event technologies**

| Bt Event | Commercial Sources | Endotoxin |
|---|---|---|
| 176 | KnockOut (Novartis)<br>NaturGard (Mycogen) | Cry 1A(b) |
| Bt11 | YieldGard (Novartis) | Cry 1A(b) |
| Mon810 | YieldGard (Monsanto - marketed by Cargill, DeKalb, Golden Harvest, Pioneer, and others) | Cry 1A(b) |
| DBT418 | Bt-Xtra (DeKalb) | Cry 1A(b) |
| CBH351 | StarLink (Aventis marketed by AgriPro, Garst, others) | Cry 9c |

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# Bt corn

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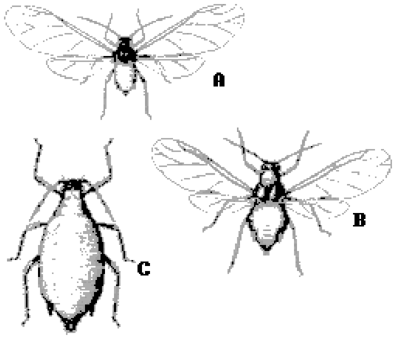
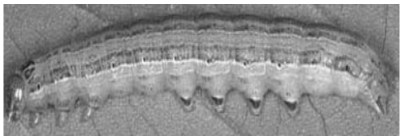
Bt corn will not let you forget about other insect pests. Table 2 gives the major corn pests and the expected effect on them by Bt corn.



**Corn leaf aphid. A, Adult male. B, Adult female - winged. C, Adult female -wingless.**

Bt corn should be used only where the risk of European corn borer infestation is high. Colorado State University Cooperative Extension entomologists recognize the following European corn borer risk areas:

**Zone 1 (Burlington, Bonny Dam, Kirk):** Use non-Bt corn hybrids, scout for insect pest problems and apply appropriate insecticides. The Kirk area has a long (4 to 5 week) 2nd generation flight in some years and Bt corn hybrids might be an appropriate choice for these situations.



armyworm

**Zone 2 (Yuma, Clarkville, Holyoke):** The Bt trait is appropriate for late planted or late maturing hybrids in these areas.

**Zone 3 (Eckley, Wray, Wauneta):** Bt hybrids are recommended for this area, regardless of planting date or maturity.

Development of insect resistance to endotoxins is a major concern for all Bt-modified crops because so much selective pressure is put on the pest. Because some Bt events are not as high dose as others and some areas are considered to be more likely to develop resistance than others, the EPA has prohibited the sale of hybrids containing events 176 (KnockOut) and DBT418 (Bt-Xtra) in the following Colorado counties- Baca, Bent, Cheyenne, Kiowa, Kit Carson, Otero, and Prowers.

Refuge strategy is also being used by the EPA to impede the development of insect resistance to Bt. It assumes that if a certain (refuge) acreage is planted to non-Bt hybrids then any corn borers coming out of these areas will be susceptible to Bt. They will mate with any survivors from the Bt corn and preserve the genetic susceptibility of the overall population. Current EPA policy restricts Bt acreage to 80% of total corn acreage. Refuges for a given planting of Bt corn should be no further than ½ mile away. If spraying of the refuge with a corn borer insecticide is likely then the non-Bt corn refuge should be planted within ¼ mile of the Bt corn. The non-Bt corn refuge can be planted as strips (at least 6 rows wide) running the length of the field.

corn earworm

cut worm

corn rootworm

There may be difficulty in marketing Bt corn destined for international markets. Imports are generally approved by event. For example, DBT 418 and CBH 351 are not currently (2/1/2000) approved for all of our major export markets. Even if a Bt event is approved, other traits (e.g. herbicide resistance) stacked with Bt may not be approved. International markets change rapidly, so it is impossible to know what the rules will be at harvest this fall.

*(Continued on page 13)*

# Bt corn

(Continued from page 12)

**Table 2. Effect of Bt technology on other corn pests.**

| CORN PEST | EFFECT OF BT CORN | COMMENTS |
|---|---|---|
| Armyworm | Not controlled | Some effect on growth rates, some control may occur if infestation starts with small larvae. Potential for control with other Δtx forms |
| Corn rootworm adults | Not controlled | |
| Corn rootworm larvae | Not controlled | Hybrids with Δtx toxic to rootworm larvae are expected on a limited basis in 2001. |
| Corn leaf aphid | Not controlled | Less insecticide use for corn borers could make aphid less of a problem since outbreaks may be triggered by chemical control of other pests. |
| Corn earworm | Some control with some events. | Mon810 and Bt11 are moderately effective. Will not control late season infestations. Will control larvae that feed in whorl early in season (not common). |
| Cutworms | Not controlled | |
| European corn borer | Controlled | Main target of Bt corn. Research results indicate 100% control of first generation and slightly lower control of second generation. Events 176 and DBT418 not as effective against second generation. |
| Fall armyworm | Not controlled | |
| Grasshoppers | Not controlled | |
| Southwestern corn borer | Controlled | Not tested as much as European corn borer, but results by event have been comparable. |
| Spider mites | Not controlled | Less insecticide use for corn borers could lower spider mites risk since outbreaks may be triggered by chemical control of other pests. |
| Western bean cutworm | Not controlled | |
| Wireworms | Not controlled | |

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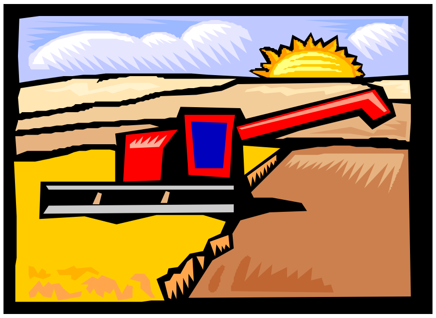
# Grain Handling Practices Preserve Identity

## Identity Preserved (IP) grain handling practices evolved as a response to buyer's demand for trait-specific products.

Identity Preserved (IP) grain refers to specialty production, segregation, and identification of food grade crop varieties through specialty marketing channels so the end user of the product is assured that the specific variety is pure and meets certain standards. IP grain crops are grown and handled under controlled conditions and delivered for specialty use or as GMO free. In traditional commodity grain production, high and low quality grain lots are often blended to achieve an acceptable level of grain quality. To qualify a grain lot as IP, producers must follow rigid cultural and handling practices required for quantity and uniformity. Typically a contract grower agrees to produce, harvest, store and deliver the grain without mixing with other varieties. The process begins with planting pure seed of a given hybrid or variety, usually planted on land that has not grown that crop for at least a year. Often field isolation distances are required as part of the production plan. Independent third party record keeping, field inspections and lab testing services are used to monitor the IP process.



IP grain crops usually are inspected one or more times during the growing season to assure freedom from (or removal of) weeds or other crops, and that other specific standards are met in order to meet end user contract requirements. IP food grade crops are carefully harvested to avoid mechanical damage, other crops, and dirt stains. Clean equipment is used, with the grain stored in clean dry bins, aerated periodically to control moisture and moved to market in clean cargo containers, bags, or via clean trucks. Biochemical methods have been developed to distinguish between certain crop varieties. For example, a gel electrophoresis method of identification based on seed storage protein differences has been developed for malting barley. In this case, grain samples are evaluated for variety purity by malting and brewing companies in their laboratories or are evaluated by outside laboratories.

In Colorado, a new company called Identity Preserved International, Inc. (IPI), located in Lakewood, seeks to match growers with buyers to produce and market trait-specific crops. The company will create databases by gathering information including producer's acreages, soil types, on-farm storage capacity, type of harvesting equipment, transportation capabilities, locations, and use of Global Positioning System technology. Another database will include the buyer's requirements for specific traits. The mission of the company is to match up the needs of the buyer with producer's crops that meet those needs.

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# websites. . .

http://www.cast-science.org/castpubs.htm
Council for Agricultural Techonolgy site with information about GMOs.

http://www.fda.gov
Food and Drug Administration, click on Bioengineered Foods.

http://ificinfo.health.org
International Food Information Council, click on Food Safety and Nutrition Information.

http://www.aphis.usda.gov/oa/new/ab.html
Ensuring the safety of the products of agricultural biotechnology is an important goal of USDA's Animal and Plant Health Inspection Service (APHIS). APHIS regulates the field testing, importation and interstate movement of genetically engineered organisms, plants, and plant products. APHIS also regulates genetically engineered veterinary biologics. This page provides links to APHIS biotechnology activities as well as to other pages dealing with biotechnology.

http://www.acpa.org/public/issues/biotech/indexbiotech.html
American Crop Protection Association

http://www.usia.gov/topical/global/biotech/
U.S. Department of State International Information Programs, click on "Biotechnology creates gene revolution."

http://www.foodbiotech.org/
Food Biotechnology Communications Network, from Canada, click on News Items for current information.

http://www.fao.org/ag/magazine/9901sp1.htm
Food and Agriculture Organization of the United Nations. Biotechnology in agriculture - While respecting ethical concerns, governments should recognize biotechnology's potential for increasing food supplies and alleviating hunger.

http://www.betterfoods.org/
The Alliance for Better Foods, Click on "Biotech and U.S. Agriculture" and/or "Environmental Benefits."

http://www.fb.org/
American Farm Bureau