GENETIC ENGINEERING OF CROP PLANTS

WHAT FARMERS NEED TO KNOW ABOUT TRANSGENIC CROPS

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Abstract: This publication attempts to define for farmers and ranchers some of the key issues related to transgenic crops. It explains what genetic engineering is, and examines the costs and benefits to farmers of transgenic versus conventional crop varieties. However, this publication cannot provide definitive answers or recommendations because independent scientific and socioeconomic analyses of transgenic crops are limited, with many questions still unanswered. In addition, how well transgenic technology works for farmers depends on the characteristics of each specific crop variety, the system in which it is placed, the skill with which it is managed, and the markets for which it is destined.

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What Are Transgenic Crops?

The term *biotechnology* refers to a broad spectrum of technologies—including conventional plant selection and breeding—in which humans intervene in biological processes of genetic alteration and improvement. The focus of this paper is on crop varieties created through a type of biotechnology commonly known as *recombinant DNA, genetic engineering (GE), transgenic modification,* or *genetic modification (GM)*. The products of genetic engineering are often called *genetically modified organisms,* or *GMOs*. All these terms refer to methods of recombinant DNA technology by which biologists splice genes from one or more species into the DNA of crop plants to transfer chosen genetic traits.

Genes are segments of DNA that contain information that in part determines the structure and function of a living organism. Genetic engineers are molecular biologists who manipulate this information, typically by taking genes from one species—an animal, plant, bacterium, or virus—and inserting them into another species, such as an agricultural crop.

With the advent of genetic engineering of plants around 1983, it appeared that this new biotechnology would benefit and even revolutionize agriculture. The transfer of desirable genetic traits across species barriers has shown promise for solving problems in the management of agricultural crops (1). Potential benefits include reduced toxic pesticide use, improved weed control resulting in less tillage and soil erosion, and water conservation. However, "emerging evidence suggests the promised environmental benefits remain small, uncertain or unrealized in the U.S., and some risks are real" (2).

How Is Gene Transfer Accomplished?

Knowing how gene transfer occurs in the laboratory is key to understanding how the desired traits express themselves in the resulting crop plants, and why unintended effects, such as the production of allergens, may also be present or develop with subsequent generations of plants.

Plants have elaborate defense mechanisms for dealing with foreign substances, including foreign DNA. To overcome these defense mechanisms, genetic engineers include pathological organisms in the complex DNA packages they create to carry the chosen gene into the host cell.

Generally, there are four parts to a DNA package (3):

1. Genes for the *desired trait*—the "payload." An example of such a trait is crop resistance to a given herbicide.

2. Genes for carrying the package into the host plant's DNA. This genetic carrier is called the *vector* and is usually taken from a bacterium that causes tumors in plants, *Agrobacterium tumefaciens.* Viruses are also sometimes used as gene carriers. These bacterial or viral vectors infect the new host cells, delivering the engineered gene into the DNA of the host plant.

3. Genes for ensuring that the genetic package will express the desired trait persistently (rather than weakly or not at all). These genes "turn on" the desired trait and are called *promoters*. They are usually derived from the cauliflower mosaic virus (CaMV).

4. Genes for helping the biologist find the DNA segment in which the insertion has been successful. These genes are called *markers* and are resistant to antibiotics (usually neomycin or kanamycin). When the antibiotic is applied to the new host's cells, the cells that survive are the ones carrying the successfully inserted antibiotic-resistant gene—indicating a likelihood that the gene carrying the desired trait has been successfully inserted as well. Marker genes are usually derived from bacteria (*E. coli*).

An alternative vector method uses a particle gun to shoot tiny metal particles with the DNA package attached into the new host cell. This eliminates the need for a bacterial vector, but adds to the potential for genetic disruption in the host cell (4).

How does this process sometimes result in *unintended effects*?

The current methods of gene transfer are not precise. While scientists can control with relative exactness the "trait gene" that is inserted into a host plant genome, they cannot yet control its location, nor the number of copies that get inserted. *Location* of genetic material is important because it controls the expression of biological traits just as genes themselves do. Also, inserted DNA frequently contains *multiple copies*, which are often scrambled. Multiple copies can "silence" genes, resulting in instability in the introduced genes. Because scientists can control neither the location nor copies of the genetic material they are inserting, they cannot entirely control the traits the host plant will express, nor can they guarantee genetic stability in subsequent generations (5). This can lead to unpredictable and undesirable effects, examples of which include plant infertility, the production of toxins, and reductions in yield and plant fitness.

Another characteristic that can result in unintended effects is called *pleiotropy*. Pleiotropy means that one gene controls multiple traits in an organism. In other words, the gene for a desired trait may also control other traits in the crop plant. Genetic engineers have relied on a simpler model of gene expression, assuming one gene controls one particular trait. But pleiotropy is common, and the interactions of genes with each other and their environment add further complexity. In short, it is difficult or impossible to predict what the effects of new genetic combinations will be.

The current *marker and promoter genes* of choice also create new hazards. The antibiotic-resistant marker genes carry the potential to increase the number of bacteria that are resistant to antibiotics. The viral promoter genes could combine with other infecting viruses to create new viruses. The very powerful promoter commonly used, the cauliflower mosaic virus, can cause the inserted DNA package to be expressed out of proportion with the rest of the genetic code. With the particle gun method especially, this promoter can also jump out of the DNA package and land somewhere else in the host genome, causing disruption. The bacterial and viral *vector genes* can recombine to form active pathogens once again—either new ones, or old ones with renewed virulence, or with broader host specificity (3).

Each piece of the gene package described above carries with it the potential to disrupt non-target portions of the host plant's DNA, to create instability in the new genetic construct, or to result in unpredictable combinations that can create new substances, viruses, or bacteria. What this adds up to is the possibility of unintended effects, particularly in subsequent generations of the engineered plant.

Lessons from the human genome project

Genetic engineering of crops is based upon the notion that genes alone determine species traits. But this assumption—and the resulting idea of simply transferring a single gene between organisms to achieve a single result—contradicts recent discoveries in genetic science. Inheritance and expression of traits are controlled by complex processes involving complicated genetic material that includes more than simple genes. For example, so-called junk DNA is now thought to play a significant role in determining an organism's traits.

Mapping of the human genome, completed in early 2001, revealed that humans contain about one-third the number of genes scientists expected to find. In fact, the 30,000 human genes they identified comprise only 1 percent of the total human DNA; they don't know what much of the other 99 percent is for. Only 300 genes in the human genome are not also in the mouse. "This tells me genes can't possibly explain all of what makes us what we are," said Craig Venter, president of Celera Genomics, the Maryland firm that led one of the mapping teams (6).

Commercial Transgenic Crops and Their Traits

While increased yields and improved nutritional value are among the promised benefits of transgenic crops, most genetically engineered crops now planted worldwide are designed either to 1) survive exposure to certain herbicides (called herbicide-tolerant crops) or 2) kill certain insect pests (called pesticidal or insecticidal crops).

Genetically engineered herbicide-tolerant crops have been altered to withstand being sprayed with broad-spectrum herbicides, with the idea that one application will take care of most types of weeds without killing the crop. Insecticidal crops contain genes of the soil bacterium *Bacillus thuringiensis* (Bt). These Bt genes cause the plants to produce a chemical toxic to the European corn borer, the cotton bollworm, and other caterpillars. (Caterpillars are the larvae of insects in the Lepidoptera order, which includes moths and butterflies).

Herbicide-tolerant crops accounted for 71 percent of the acreage planted, worldwide, to genetically engineered crops in 1998 and 1999. Pesticidal crops, or a combination of pesticidal and herbicide-tolerant crops, accounted for most of the remaining acreage (7).

More than 100 million acres of the world's farmland were planted with transgenic crops in the year 2000. The United States, Argentina, and Canada are the world's leading producers of genetically engineered crops, with the U.S. first at 71 percent of the world's total acreage. Transgenic crops are being shipped to or experimented with in many other countries, including China, India, Australia, and South Africa (8).

In 1999, one-quarter of U.S. farmland was planted to transgenic crops. To date, soybeans and corn cover the most transgenic acres. In 2001, more than 60 percent of soybeans planted in the U. S. were estimated to be transgenic—specifically, tolerant to Monsanto's broad-spectrum herbicide, Roundup™ (glyphosate) (9). Transgenic corn planted in the U.S. offers both insecticidal and herbicide-tolerant traits, though Bt insecticidal corn predominates.

Other large-acreage transgenic crops include cotton and canola. Most transgenic cotton is herbicide-tolerant, though some varieties have the Bt trait; transgenic canola is herbicide-tolerant. The first transgenic wheat, planned for commercial introduction in 2003, is Roundup-tolerant.

Other traits engineered into commercial transgenic varieties include disease resistance, high pH tolerance, and several nutritional, taste, texture, and shelf-life characteristics (10). Other transgenic crops currently on the U.S. market include tomatoes, potatoes, sunflowers, peanuts, and sweet mini-peppers. More transgenic crops, including rice, are under development for commercial release in the next several years (10).

However, there is evidence that biotechnology firms may be changing course because of deepening consumer skepticism and tighter regulation worldwide, which are increasing the costs and business risks of new transgenic crop introductions. A Monsanto spokesman was quoted in the Christian Science Monitor in August 2001, saying, "We're focusing on four core crops—corn, oilseeds, cotton, and wheat," the major crops in North America with the most acreage and profit potential (11). For a more complete list of current and future commercial transgenic crops and their traits, see <http://www.bio.org>, the website of the Biotechnology Industry Organization.

Unresolved Issues of Concern

There are many unanswered questions about transgenic crops and their potential benefits, costs, and risks. In fact, according to a recent independent survey of research data on transgenic crops, conducted by the Winrock

Foundation's Henry A. Wallace Center for Agricultural and Environmental Policy, "The varieties and uses of genetically altered crops have grown much more rapidly than our ability to understand...them." The study revealed that only four percent of total federal agricultural biotech funding is dedicated to environmental assessment (12).

Following is a brief discussion of some prominent transgenic-crop-related issues facing farmers and ranchers. Whether a producer is growing transgenic crops, is considering growing them, has fields adjoining them, or has markets sensitive to transgenic crops, these issues are relevant. The purpose of the following discussion is not to provide a thorough treatment of each issue, but to explain in summary fashion what farmers and ranchers should be aware of, and to help them make sense of contradictory claims and stories.

1. Ecological Issues

Gene flow to neighboring crops and to related wild species

Ecological scientists have little doubt that *gene flow* from transgenic fields into conventional crops and related wild plants will occur. Gene flow from transgenic to conventional crops is of concern to farmers because of its potential to cause herbicide resistance in related conventional crops. For example, in western Canada, three different herbicide-resistant canola varieties have cross-pollinated to create canola plants that are resistant to all three types of herbicide. Through what is called gene-stacking, this new triple resistance has turned volunteer canola into a significant weed problem (13).

Gene flow from transgenic crops to wild relatives creates a potential for wild plants or weeds to acquire traits that improve their fitness, turning them into "super weeds." For example, if jointed goatgrass—a weedy relative of wheat—acquires the herbicide-tolerant trait of Roundup Ready wheat, it will thrive in crop fields unless applications of other herbicides are made. There is already evidence of such outcrossing from herbicide-resistant wheat to jointed goatgrass. Frank Young and his colleagues at Washington State University found that imidazolone-resistant wheat (not a transgenic variety) outcrossed to goatgrass in one season (14). Other traits that wild plants could acquire from transgenic plants that would increase their weediness are insect and virus resistance (2).

Because of their experience with classically bred plants, few scientists doubt that genes will move from crops into the wild: seven of the world's thirteen most important crop weeds have been made weedier by genes acquired from classically bred crops (13). Because gene flow has the potential to affect farmers' crop and pest management, crop marketability, and liability, more research needs to be done to determine the conditions under which gene flow from transgenic plants is likely to be significant.

Pesticide resistance in insect pests

Bt has been widely used as a microbial spray because it is toxic only to caterpillars. In fact, it is a pest management tool that organic farmers depend on—one of the few insecticides acceptable under organic rules. Unlike the commercial insecticide spray, the Bt engineered into crop plants is reproduced in all, or nearly all, the cells of every plant, not just applied on the plant surface for a temporary toxic effect. As a result, the possibility that transgenic Bt crops will accelerate insect pests' development of resistance to Bt is a serious concern. Pest resistance to Bt would remove this valuable and environmentally benign tool from farmers' and forest managers' pest control toolbox. For more on Bt pest resistance, see <http://www.pmac.net/ge.htm> (*Pest Management at the Crossroads*).

Antibiotic resistance

As described in the earlier section on how gene transfer is accomplished, the use of antibiotic-resistant marker genes for the delivery of a gene package into a recipient plant carries the danger of spreading antibiotic-resistant bacteria. The likely result will be human and animal health diseases resistant to treatment with available antibiotics. Research is needed on antibiotic resistance management in transgenic crops (15). Already the European Commission's new rules governing transgenic crops stipulate phasing out antibiotic-resistant marker genes by the end of 2004 (5).

Effects on beneficial organisms

Evidence is increasing that transgenic crops—either directly or through practices linked to their production—are detrimental to beneficial organisms. New studies are finding that Bt crops exude Bt in concentrations high enough to be toxic to some beneficial soil organisms (16). In addition, a study by University of Arkansas scientists has shown that "root development, nodulation and nitrogen fixation are impaired" in some varieties of Roundup Ready soybeans (17). The reason is that the beneficial rhizobium responsible for nitrogen fixation in soybeans is sensitive to Roundup. It also appears that disruption of beneficial soil organisms can interfere with plant uptake of phosphorus, an essential plant nutrient (18).

Beneficial insects that prey on insect pests can be affected by insecticidal crops in two ways. First, the Bt in transgenic insecticidal crops has been shown in some laboratory studies to be toxic to ladybird beetles, lacewings, and monarch butterflies (2). The extent to which these beneficials are affected in the field is a matter of further study. Second, because the insecticidal properties of Bt crops function even in the absence of an economic threshold of pests, Bt crops potentially can reduce pest populations to the point that predator species are negatively affected (19).

Reduced crop genetic diversity

As fewer and larger firms dominate the rapidly merging seed and biotechnology market, transgenic crops may continue the trend toward simplification of cropping systems by reducing the number and type of crops planted. In addition, seed-saving, which promotes genetic diversity, is restricted for transgenic crops (20).

2. Food Safety

Because food safety is predominantly a concern of consumers, this paper does not include a discussion of it. However, because food safety issues do impact marketing and international trade, here is a short list of consumer safety concerns about transgenic food:

- possibility of toxins in food
- possibility of new pathogens
- reduced nutritional value
- introduction of human allergens
- transfer of antibiotic resistance to humans
- unexpected immune-system and genetic effects from the introduction of novel compounds

It is in part because of these concerns that consumer demand for organically grown crops continues to increase.

Allergenicity

StarLink corn, a transgenic variety, contains the Cry9C protein, which protects the growing plant from pests. In 1998, federal regulators approved Starlink for livestock feed and ethanol, but banned it in human food because of concerns that the protein could cause allergic reactions. Yet, by the fall of 2000, StarLink had found its way into taco shells shipped around the world. Many people reported allergic reactions after eating foods later discovered to contain StarLink. However, proving a link to StarLink was difficult because the products containing it were not labeled and people ate it unknowingly. Aventis, the company that developed and patented StarLink, asked the U.S. Environmental Protection Agency (EPA) to approve it for human consumption after the fact in order to avoid the costs of removing it from the world's market. In July 2001, a U.S. science advisory panel recommended to the EPA that it maintain its ban on StarLink corn in human food. The science panel reaffirmed that the Cry9C protein in StarLink corn is likely to be a human allergen (21).

3. Farm Management Issues

The most widely planted transgenic crops on the market today can simplify short-term pest management for farmers and ranchers. In the case of herbicide-tolerant crops, ideally farmers can use a single broad-spectrum herbicide for all their crop weeds, though they may need more than one application in a season. By planting insecticidal crops, farmers can eliminate the need to apply pesticides for caterpillar pests like the European corn borer or the cotton bollworm, though they still have to contend with other crop pests.

While these crops offer handy pest control features, they may complicate other areas of farm management. Farmers who are growing both transgenic and conventional varieties of the same crop will need to segregate the two during all production, harvesting, storage, and transportation phases if they are selling into differentiated markets or plan to save their own seed from their conventional crops. Read about the steps necessary for on-farm segregation in **Appendix 1**.

To minimize the risk of gene flow from transgenic to adjacent conventional crop fields, federal regulations require *buffer strips* of conventional varieties around transgenic fields. Different transgenic crops require different buffer widths. Because the buffer strips must be managed conventionally, producers have to be willing to maintain two different farming systems on their transgenic fields. Crops harvested from the buffer strips must be handled and marketed as though they are transgenic.

Planted *refuges*—where pest species can live outside fields of insecticidal and herbicide-tolerant transgenic crops—are also required to slow the development of weed and insect pest resistance to Bt and broad-spectrum herbicides. These refuges allow some individuals in the pest population to survive and carry on the traits of pesticide susceptibility. Requirements governing the size of refuges differ according to the type of transgenic crop grown.

Farmers growing herbicide-tolerant crops need to be aware that *volunteer crop plants* the following year will be herbicide-resistant. This herbicide resistance makes no-till or direct-seed systems difficult because volunteers can't be controlled with the same herbicide used on the rest of the crop. In a no-till system that relies on the same broad-spectrum herbicide that the volunteer plants are resistant to, these plants will contaminate the harvest of a following conventional variety of the same crop, a situation farmers need to avoid for two reasons. First, the contamination means a following conventional crop will have to be sold on the transgenic market. This leads to the second reason. If farmers grow and market a transgenic crop for which they do not have a technology agreement and did not pay royalty fees, they face possible prosecution by the company that owns the transgenic variety. Many farmers have been charged with "theft" of a company's patented seed as a result of contamination in the field (22).

Farmers growing insecticidal crops need to recognize that insect pressure is difficult to predict and may not warrant the planting of an insecticidal variety every year. In a year when pest pressure is low, the transgenic seed becomes expensive insurance against the threat of insect damage (23).

Farmers growing transgenic crops need to *communicate* with their neighbors to avoid contaminating their fields and to ensure that buffers are adequate. In Maine, farmers growing transgenic crops are now required by law to be listed with the state agriculture department, to help identify possible sources of cross-contamination when it occurs. The new law, L.D. 1266, also "requires manufacturers or seed dealers of genetically engineered plants, plant parts or seeds to provide written instructions to all growers on how to plant, grow, and harvest the crops to minimize potential cross-contamination of non-genetically engineered crops or wild plant populations" (24).

Farm management issues common to all transgenic crops include yield, cost, price, profitability, management flexibility, sustainability, market acceptance, and liability. Many of these issues are described in **Appendix 1**—an article specific to transgenic corn and soybean production, but one that all growers will find useful. Yield and profitability, market acceptance, and liability are also discussed in separate sections below.

4. Crop Yield, Costs, and Profitability

Some farmers will get higher yields with a particular transgenic crop variety than with their conventional varieties, and some will get lower yields. The same is true for costs. Some producers will see their overall profitability rise, and some will see it drop. If the results of research studies so far on yield, chemical use, costs, crop prices, and profitability of these crops seem contradictory, it is because farmers and farms are not all alike. Neither are the conventional varieties used for comparison.

Some yield, cost, and profitability trends do appear to be emerging from the growing body of research data for transgenic crops, however. As noted in the Wallace Center report, Roundup Ready soybeans were designed simply to resist a particular chemical herbicide, not to increase yields. In contrast, Bt corn and cotton, by resisting insect pests, may result in higher yields from reduced pest pressure (25).

Yield: herbicide-tolerant crops – soybeans, cotton, canola

Herbicide-tolerant soybeans appear to suffer what's referred to as a "yield drag." Again, in some areas and on some farms this tendency of Roundup Ready soybean varieties to yield less than their comparable, conventional counterparts varies, but overall, they appear to average yields that are five to ten percent lower per acre (26). As described earlier, impaired root development, nodulation, and nitrogen fixation likely account for this yield drag. Drought conditions worsen the effects. The bacterium that facilitates nodulation and nitrogen fixation in the root zone apparently is sensitive to both Roundup and drought (27).

In addition, University of Missouri scientists reported problems with germination of Roundup Ready soybeans in the 2001 crop year (28).

Yields of herbicide-tolerant cotton are reportedly not significantly different from those of conventional cotton (29).

Herbicide-resistant transgenic canola varieties yield less on average than conventional canola varieties. Transgenic canola costs less than conventional canola to produce, but because of its higher yields conventional canola returns more profit per acre (30).

Yield: insecticidal crops – corn, cotton

Insecticidal Bt corn and cotton generally yield higher "in most years for some regions" according to USDA Economic Research Service data from 1996 to 1998. Bt cotton, especially, outpaces yields of conventional cotton by as much as 9 to 26 percent in some cases, though not at all in others. Yield increases for Bt corn have not been as dramatic (31). Time will tell whether farmers can expect yield increases or decreases in the long run with these and other transgenic crop varieties.

Changes in chemical pesticide use

One of the promises of biotechnology is that it will reduce pesticide use and thereby provide environmental benefits and reduce farmers' costs. The herbicide-tolerant and insecticidal varieties are designed specifically to meet these goals.

Studies estimate a two to three percent decrease in U.S. pesticide use, but the effects vary widely by crop, region, and year. Increased future pesticide use resulting from the buildup of resistance to heavily used herbicides is a long-term concern (32). Pesticide use depends on the crop and its specific traits; weather; severity of pest infestations; farm management; geographic location of the farm; and other variables. As a result, conclusions drawn by various studies analyzing pesticide use on transgenic crops remain controversial. According to the Wallace Center report, in a review of the data available up through 2000, crops engineered to contain Bt appear to have decreased the overall use of insecticides slightly, while the use of herbicide-resistant crops has resulted in variable changes in overall herbicide use, with increases in use of some herbicides in some places and decreases in others (33).

The crop for which studies are showing the largest decrease in pesticide use is Bt cotton, with Bt corn resulting in only small changes. Herbicide-tolerant cotton has also resulted in little change in herbicide use (2).

The data for herbicide-tolerant soybeans seems harder to sort out. A recent study of herbicide use data on Roundup Ready soybeans by Dr. Charles Benbrook, former executive director of the National Academy of Sciences Committee on Agriculture and now with the Northwest Science and Environmental Policy Center, concludes that the use of herbicides has actually *increased* because the weeds have become resistant to Roundup (34). While another recent study by Netherlands scientists shows a decrease in herbicide use on transgenic soybeans, it is clear that weed resistance to Roundup may lead to increased herbicide use and to the need to shift to more toxic compounds in the future (2). American Soybean Association president Tony Anderson agrees that the developing resistance of weeds to herbicides such as Roundup is a problem (35).

The Wallace Center report emphasizes the importance of ongoing monitoring of pesticide use data. If farmers abandon integrated pest management, which utilizes a variety of pesticide and cultural control methods, in favor of the simplified control offered by herbicide-resistant and insecticidal transgenic crops, then early findings of reduced pesticide quantities and toxicity may not hold over the long run (36). Refer to chapter one of the Wallace Center report (12) for USDA pesticide use data comparisons between transgenic and conventional crops, broken down by crop.

Profitability

Farmers need to consider all the factors that determine profitability. No single factor can tell the whole story. Transgenic crop seeds tend to be more costly, and farmers have the added expense of a substantial per-acre fee charged by the owners of transgenic varieties. These costs have to be considered along with input cost changes—whether herbicide or insecticide use and costs go down, go up, or stay the same. Market price is another factor: Prices for some transgenic crops in some markets are lower than prices for comparable conventional crops, though rarely are they higher. Farmers need to watch the markets. Some buyers will pay a premium for a non-transgenic product, though as transgenic seeds find their way into conventional transportation, storage, and processing streams, these premiums may disappear along with confidence that "GMO-free" products are in fact truly free of engineered genes.

5. Marketing and Trade

Buyer acceptance is a significant marketing issue for farmers raising transgenic crops. Farmers need to know before they plant what their particular markets will or won't accept. Since most grain handlers cannot effectively segregate transgenic from non-transgenic crops in the same facility, many companies are channeling transgenic crops into particular warehouses. Farmers need to know which ones and how far away those are.

Many foreign markets tend to be more leery of transgenic products than domestic markets, though trade in transgenic livestock feed is more liberal than trade in transgenic human food. The widespread contamination of corn in the U.S. with the Cry9C Bt transgene (StarLink), which is not approved for human consumption, has resulted in even further resistance on the part of buyers to purchasing transgenic products for human food. According to a report in Britain's *The Guardian*, "No new transgenic crops have been approved by the European Union (EU) since

April 1998, and a defacto moratorium on further approvals has been in place since June 1999" (37). Some countries have banned altogether the production and importation of transgenic crops and food products (Sri Lanka and Brazil), while many others have put in place partial bans or mechanisms to slow their approval for importation or production.

While the European Union officially lifted its two-year moratorium on the introduction of new transgenic crops in February 2001, during the debate over labeling and traceability regulations the moratorium remains in effect. Under the proposed new EU requirements, "all foods and animal feed derived from GMOs have to be labeled and, in the case of processed goods, records have to be kept throughout the production chain allowing the GMO to be traced back to the farm" (38). If approved, the new regulations will hamper the export of U.S. farmers' products to the EU because the U.S. does not require traceability or labeling of transgenic crops.

Europe's Proposed Rules *(5)*

In July 2001, the European Commission adoped a new directive regulating the release of transgenic organisms, including plants, animals, and microorganisms. In its main provisions, European Directive 2001 / 18 / EC requires the labeling of all products containing GMOs—including processed ingredients—and guarantees traceability from field to plate. Long-term monitoring of transgenic crops following their release is required, as well as molecular documentation of their genetic stability. The directive guarantees the public's access to information about the release and content of GMOs, and the opportunity for comment prior to a proposed release. The directive also stipulates s phasing-out of antibiotic-resistant marker genes by the end of 2004.

If the Commission's directive is approved by the member states of the European Union, all GMOs will eventually have to satisfy its requirements before going to market. Compliance with the requirement to document genetic stability may be the most difficult provision to meet, since instability is a common characteristic of current DNA transfer methods (see *How Is Gene Transfer Accomplished?* above). However, approval under the old directive for any transgenic crop already on the market in the European Union will be retained.

While the U.S. does not require mandatory labeling of processed food containing transgenic ingredients, the European Union, Russia, Czech Republic, Japan, South Korea, Taiwan, Australia, New Zealand, and Ecuador do (39). Because many domestic merchandisers of agricultural commodities do not segregate transgenic from conventional crop varieties, it is impossible for them and the farmers that supply them to serve these food markets.

Twenty percent of corn and 8 percent of soybeans produced in the U.S. are exported, and more than 80 percent of these crops is used in animal feed. Overseas market restrictions on transgenic crops in the feed sector are less stringent than those for food (40). In contrast, 48 percent of U.S. wheat is exported, with nearly half of this *food* crop going to countries that are resistant to buying transgenic food, particularly Japan and European nations. Because wheat producers are so dependent on exports, they are approaching the introduction of the first transgenic wheat, expected as soon as 2003, with caution. The Japanese milling industry has made it clear that it does not want transgenic products. As a result, Monsanto has promised not to introduce its Roundup Ready wheat until Japan gives its approval (41). At least two states, North Dakota and Montana, have considered legislation that would place a state moratorium on the introduction of transgenic wheat. For more about the wheat industry's reaction to the anticipated introduction of Roundup Ready wheat, see **Appendix 2**.

In addition to national and international policies on the use and importation of transgenic crops, many countries' processors and retailers have set their own corporate policies. Major retail chains in Europe and the U.S. have declared their commitment to avoiding the purchase of transgenic products, both feed and food.

For buyers who don't want transgenic products, the likelihood of contamination of non-transgenic products with engineered genes is troublesome. Since 1997, the European Union has effectively barred U.S. corn imports over the possibility that genetically engineered varieties unapproved in the EU have mixed with sanctioned crops. This has cost American farmers access to a $200 million-a-year market (42).

Organic farmers face even bigger marketing and trade risks, since their buyers can accept no transgenic contamination. The organic industry does have a system for segregation, but recent tests for transgenic material in organic products demonstrate that it is not immune to contamination from conventional systems (43). The markets organic farmers have enjoyed, and those that producers of non-GE conventional crops could build upon, will likely disappear if contamination of their products continues to spread.

Until the issues of trade in transgenic crops and food products, and their labeling and traceability, are resolved in international trade arenas, the markets for U.S. transgenic crops will remain uncertain. Changes in what any particular country will or won't accept are occurring all the time, and producers of crops for export are well advised to stay informed of these changes.

Segregation of transgenic crops and liability for cross-contamination of conventional and organic crops are issues that obviously overlap with those of marketing and trade. These issues are discussed further in the following section on liability.

6. Liability

The need to separate transgenic crops from conventional and organic ones opens farmers to liability for their product at every step from seed to table. Effective systems for segregation do not exist at present, and will be costly to develop and put into place (44). Farmers may well end up bearing the added costs of crop segregation, traceability, and labeling.

In the meantime, farmers who grow transgenic varieties—and, ironically, those who do not—are liable for transgenic seeds ending up where they aren't wanted: in their own non-transgenic crop fields, in neighbors' fields, in truckloads of grain arriving at the elevator, in processed food products on retail shelves, and in ships headed overseas.

Farmers who choose not to grow transgenic varieties risk finding transgenic plants in their fields anyway, as a result of cross-pollination via wind, insects, and birds, which may bring pollen from transgenic crops planted miles away. Besides pollen, sources of contamination include contaminated seed and seed brought in by passing trucks or wildlife. Those farmers whose conventional or organic crops are contaminated, regardless of the route, risk lawsuits filed against them by the companies that own the proprietary rights to seed the farmer didn't buy. Likewise, farmers who grow transgenic crops risk being sued by neighbors and buyers whose non-transgenic crops become contaminated.

Because contamination by transgenic material has become so prevalent in such a short time, all farmers in areas of transgenic crop production are at risk. Insurance, the most common recourse for minimizing potential losses because of liability, is not available to the nation's farmers for this risk because insurance companies do not have enough information to gauge the potential losses.

Most of the farmers who have been accused by transgenic seed companies of illegally growing and harvesting their proprietary transgenic varieties have paid fines to the companies rather than go to court to defend themselves. One Canadian grower of non-transgenic canola, Percy Schmeiser, did go to court against Monsanto, and lost in a recent ruling that requires him to pay Monsanto the approximately US$85,000 value of his crop and $13,000 in punitive damages. See **Appendix 3** for a clear analysis of this farmer's case from the standpoint of the practicalities of farming, as well as the implications for other farmers, especially those who traditionally save their own seed for planting next year's crop.

In another example, a Texas organic farm's corn, assumed to be GE-free, was purchased by a processor who made it into organic tortilla chips. Only after the product had been sold and shipped to European retailers was it discovered to be contaminated with transgenic corn. The processor had to recall its product at a cost of over $150,000. The processor chose not to sue the organic farmer, but could have (42). The retailer, in turn, apparently did not sue the processor. Had it done so, the liability for the retailer's loss could have fallen on both the processor and the farmer.

According to a Boston Globe story, no figures on farmers' losses resulting from liability for transgenic contamination exist, but anecdotal evidence suggests that cases against farmers are becoming "far more common" (42). Until laws or legal precedent clarify the extent of farmer liability, farmers would do well to avoid making assumptions or claims about the purity of their non-transgenic products. Furthermore, producers of transgenic crops need to take all possible precautions against spreading pollen and seed to their own and others' non-transgenic fields and markets.

A full risk assessment and legal clarification of the distribution of liability among farmers, seed companies, grain handlers, processors, and retailers is needed before farmers can rest assured that transgenic crops won't result in lawsuits against them. For farmers who have adopted transgenic technology—and for those who have not—in the words of Brian Leahy, executive director of California Certified Organic Farmers, "This technology does not respect property rights" (42). In essence, farmers who grow transgenic crops on some of their fields, and farmers who grow none, risk bearing tremendous liability. This situation won't change until farmers either gain legal protection or until they all grow transgenic crops on all their fields.

7. Influence on Public Research

While transgenic crop varieties are generally the property of private corporations, those corporations often contract with public-sector agricultural research institutions for some of their development work. In fact, private investment in agricultural research, including germplasm development, has surpassed public investment in recent years (45). With this shift in funding sources, the following questions become important: Is the private sector unduly influencing the public research agenda? Are corporations directing public research in less socially valuable directions while research on, for instance, sustainable agriculture goes wanting? Are the outcomes of corporate-funded transgenic research and development by our public institutions equitable across the food and agricultural sectors? Is equity even a consideration of our public institutions when they accept this work?

Because intellectual property rights (patents) apply to living organisms, making them private property, the free flow of scientific information that has historically characterized public agricultural research is being inhibited. What are the implications for the future of agriculture and society of the secrecy that now surrounds so much of what was formerly shared public knowledge? For a brief history of intellectual property rights as they apply to living organisms, see **Appendix 4**.

These and other questions need to be addressed by citizens and their public institutions. These issues are of particular concern to farmers and consumers who would benefit from research into alternative technologies that are less costly (in every way), less risky, and more equitable. Equity requires that the economic benefits and risks of transgenic technology be fairly distributed among technology providers, farmers, merchants, and consumers.

For long-term sustainability, farmers need research that focuses on farms as systems, with internal elements whose relationships can be adjusted to achieve farm management goals (46). In contrast, transgenic crop research so far has focused on products that complement toxic chemical approaches to control of individual pest species. These are products that can be commercialized by large agribusiness or agri-chemical interests and that farmers must purchase every year. This research orientation only perpetuates the cost-price squeeze that continues to drive so many out of farming.

8. Industry Concentration and Farmers' Right to Save Seed

The broadening of intellectual property rights in 1980 to cover living organisms, including genes, has resulted in a flurry of mergers and acquisitions in the seed and biotech industries. According to the Wallace Center report, "Relatively few firms control the vast majority of commercial transgenic crop technologies. These firms have strategically developed linkages among the biotechnology, seed, and agri-chemical sectors to capture as much market value as possible. However, these tightly controlled linkages of product sectors raise serious issues of market access, product innovation, and the flow of public benefits from transgenic crops..." (47).

Unlike Plant Variety Protection—which does not allow for the patenting of individual genes, but only of crop varieties—Intellectual Property Rights prohibit farmers from saving their seed and undertaking their own breeding program, and prohibit plant breeders from using the material to create a new generation of varieties adapted to specific regions or growing conditions (48).

By 2000, agri-chemical giants DuPont and Monsanto together owned 73 percent of the corn seed producers in the U.S. (49). This kind of corporate control and concentration raises the question of whether there remains enough competition in the seed industry for seed pricing to remain competitive. As additional concentration occurs, how affordable will seed—all seed, not just transgenic seed—be for farmers? This question takes on added gravity as an increasing number of seed varieties become proprietary. Farmers can't save proprietary seed for planting and so must purchase new seed every year. In addition, farmers choosing transgenic varieties must sign a contract with the owner of the variety and pay a substantial per-acre technology fee, or royalty.

The anticipated commercial introduction of transgenic wheat represents a dramatic shift in an industry in which farmers still widely save their own seed. As non-transgenic varieties become contaminated with transgenic ones, even those farmers who choose to stick with conventional varieties will lose the right to replant their own seed. This loss has already occurred in Canada's canola industry, with Monsanto winning its court case against farmer Percy Schmeiser for replanting his own canola variety that had become contaminated with Monsanto's Roundup Ready canola. (See **Appendix 3** for the story of Percy Schmeiser vs. Monsanto.)

The adoption of transgenic crop varieties has brought with it an increasing prevalence of *contract production*. While contract production can lead to increased value and reduced risk for growers, farmers are justified in their concern about their loss of control when they sign a contract with a private company. Issues associated with contract production of transgenic crops must be considered within the broader context of a sustainable agriculture to include ownership, control, and social equity.

9. Regulation of Transgenic Crops

Much of the controversy over transgenic crops, both internationally and in the U.S., is in part a result of how the U.S. regulates transgenic crops. The federal government has determined that the commercial products of agricultural biotechnology are *"substantially equivalent"* to their conventional counterparts and that therefore no new regulatory process or structure is needed for their review and approval.

Currently, three federal agencies regulate the release of transgenic food crops in the U.S.: the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (USDA-APHIS), the U.S. Environmental Protection Agency (EPA), and the U.S. Food and Drug Administration (FDA).

USDA-APHIS: The USDA looks at how a transgenic plant behaves in comparison with its unmodified counterpart. Is it as safe to grow? The data it uses are supplied largely by the companies seeking a permit for release of the new crop. Under "fast-track" approval, a process in place since 1997, companies introducing a crop similar to a previously approved version need give only 30 days advance notice prior to releasing it on the market. According to the Wallace Center report, APHIS staff estimate that by 2000, 95 to 98 percent of field tests were taking place under simple notification rules rather than through permitting (50).

EPA: The EPA regulates the pesticides produced by transgenic crops, such as the Bt in Bt corn and cotton. It does not regulate the transgenic crops themselves. In contrast to its regulation of conventional pesticides, the EPA has set no tolerance limits for the amount of Bt that transgenic corn, cotton, and potatoes may contain (51).

FDA: The FDA focuses on the human health risks of transgenic crops. However, its rules do not require mandatory pre-market safety testing or mandatory labeling of transgenic foods.

Initially, the U.S. regulatory process for transgenic food crops required product-by-product reviews. Now, however, to simplify and speed up the process, new products can be approved based on the experience gained in reviewing earlier products. According to the Wallace Center report, the implication is that "some crops might be approved, or disapproved, without actual field testing" (52). The regulatory process, in fact, may not answer most questions about the environmental and human health risks of commercial production of these crops.

Central to the policy of substantial equivalence is the assumption that only the end *product* of transgenic technology is of concern—not the *process* of genetic modification. Canada has adopted a similar approach. Europe and other U.S. trading partners, however, have taken a more conservative approach. They focus on the *process* of genetic modification—the source of many of the environmental and human health risks of greatest concern.

How these different approaches play out in reality can be summed up simply: The U.S. and Canada assume a product is safe until it is proven to carry significant risk; the European Union, which follows the "precautionary principle," assumes the same product may carry significant risk until it can be proven safe. The science used by the two approaches is not fundamentally different. The difference is in the level of risk the different societies and political systems are willing to accept (53).

Precautionary Principle

The principle of precaution was developed specifically for issues involving ethics and risk. It is described by Katherine Barrett, project director with the Science and Environmental Health Network, as:

> …a process for decision-making under conditions of uncertainty. The principle states that when there is reason to believe that our actions will result in significant harm, we should take active measures to prevent such harm, even if cause-and-effect relationships have not been proven conclusively…. It has been invoked in many international laws, treaties and declarations on a range of environmental issues including climate change, marine dumping of pollutants, and general efforts towards sustainability [including the 2000 international Cartagena Biosafety Protocol on the transfer of 'living modified organisms']….there is growing consensus that the precautionary principle has reached the status of international customary law. (54)

The primary elements of the precautionary principle are identified by Barrett as:

1. Avoid harms to the environment that are "irreversible, persistent, bioaccumulative or otherwise serious."

2. "Anticipate and prevent potential harms at the source," rather than relying on reactive measures of mitigation, clean-up, or compensation.

3. Recognize the limits of scientific knowledge and don't expect a full and conclusive understanding of potential consequences before taking precautionary action, especially when the potential consequences are long-term, unconfined, and broad-scale.

4. Shift the burden of proof to the developers of potentially hazardous technologies.

5. Finally, some versions of the precautionary principle include analysis of the costs and benefits of precautionary action, though cost-benefit analysis "is not a sufficiently robust decisionmaking framework to stand alone" (54).

Implications for Sustainable Agriculture

In contrast to the ecological approach of sustainable agriculture, "the current generation of transgenic crops follows a pest management model like that employed for chemical pesticides—through interventions that are toxic to pests," the Wallace Center report points out. This "single-tool" approach is likely to fail in the long run because pests will successfully develop resistance that allows them to thrive (55).

Standard plant-breeding methods can potentially solve many of the same problems in agriculture that genetic engineers are working on, though there are areas in which genetic engineering can enhance traditional plant breeding. Armed with the map of an organism's genetic code, scientists can test which genes are in a plant to select more easily which ones to cross-breed. "Before we knew where the genes were, we were still breeding in the dark," according to Steven Briggs, head of genomics for Syngenta, a Swiss biotechnology giant, as quoted in the New York Times (56).

Framework for gauging a technology's impact on agricultural sustainability

The sustainability of any agricultural technology can be gauged in part by answering a series of questions that emerge from the principles of sustainable agriculture. Farmers and ranchers can ask themselves these questions in the context of their own operations to help determine whether adoption of the technology will move them away from, or toward, increased sustainability.

1. Does the technology increase genetic diversity?
2. Does it maintain a positive balance of pests and predators?
3. Does it protect or enhance soil biota?
4. Does it decrease the quantity or concentration of toxins released into the environment?
5. Does it decrease soil erosion?
6. Does it protect non-target organisms?
7. Does it help protect natural habitats?
8. Does it reduce pest populations and viability?
9. Does it increase farmers' yields? Decrease farmers' costs?
10. Does it increase farmers' market control? Management flexibility? Time?
11. Does it provide benefits to consumers? Will consumers accept it?
12. Does it help citizens globally gain better access to food?
13. Does it protect the public's access to information and improve public trust in agriculture?

If the answer to any of the above questions is no, a cautious approach to the adoption of the technology in question would seem in the interest of agricultural sustainability.

Conclusion

Evelyn Fox Keller, author of *The Century of the Gene* (57), describes the scientific understanding of genetics that originated with the discovery of DNA in 1953, and on which the current generation of transgenic crops is still based:

> For almost fifty years, we lulled ourselves into believing that, in discovering the molecular basis of genetic information, we had found the 'secret of life;' we were confident that if we could only decode the message in DNA's sequence of nucleotides, we would understand the 'program' that makes an organism what it is.

Recent scientific discoveries no longer support this theory. Outdated as it has become, the view that each genetic message comes from a distinct gene continues to drive promises of feeding the world and curing incurable diseases—a view Keller calls a now "utterly fantastic premise" (58).

Keller, a professor of History and Philosophy of Science at Massachusetts Institute of Technology, insists that the most recent scientific understanding of genetics has more to tell us about biological organization than about how to modify individual traits. In fact, the new leading-edge biotechnology will strive to capture the benefits of genetic engineering without its costs, risks, and potential genetic instability.

Molecular biologists and breeders are beginning to utilize the emerging knowledge of gene location and function to guide them in the application of conventional and innovative breeding techniques that do not rely on a transgene with promoter and marker genes (59). This is good news for sustainable agriculture, which is based on understanding how natural systems work in order to fit human enterprises into them. According to Fred Kirschenmann, organic farmer and director of Iowa State University's Leopold Center for Sustainable Agriculture, "…the real benefit of genetics seems to be derived not from the manipulation of a few genes, but from our enhanced understanding of how nature works" (58).

Regardless of the future direction of transgenic technology, one thing remains certain: Many of the unresolved issues for farmers, ranchers, and the general public will not be settled through the use of biological or natural sciences alone. Ethical and social issues are critical components in a meaningful evaluation of this controversial technology (60).

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NASULGC
1307 New York Avenue, N.W.
Suite 400
Washington, D.C. 20005-4722
202-478-6040
202-478-6046 fax

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An electronic pdf version of this 76-page report (or specific sections of it) is available at <http://www.winrock.org/transgenic.pdf>. For a hard copy costing $15 contact:
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Phone 703-525-9430 x672; email wallacecenter@winrock.org.

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Further Resources

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Most of the sources for this publication were retrieved from the Internet, an important source of current news and information about the rapidly changing field of transgenic technology. Many thanks to the Henry A. Wallace Center for Agricultural and Environmental Policy at Winrock International for permission to use the following list of Internet resources from Transgenic Crops: An Environmental Assessment (12). These Web site URLs were verified and updated Aug. 2001 by Wallace Center staff.

Governmental and Quasi-governmental Entities

Ag-West Biotech, funded by Saskatchewan's Department of Agriculture and Food: http://www.agwest.sk.ca/

- publishes *AgBiotech Bulletin*, http://www.agwest.sk.ca/e_bulletin.shtml

Australian Department of Health and Aged Care, Office of the Gene Technology Regulator (OGTR): http://www.health.gov.au/ogtr/index.htm

Belgian Service of Biosafety and Biotechnology (SBB)

- Belgian Biosafety Server, http://biosafety.ihe.be/Server.html

Biosafety Information Network and Advisory Service (BINAS), a service of the United Nations Industrial Development Organization (UNIDO)

- BINAS Online, http://binas.unido.org/binas/index.php3

Biotechnology Australia, a collaboration of five Commonwealth Government departments: http://www.biotechnology.gov.au/

Canadian Biotechnology Advisory Committee, part of Industry Canada

- Canadian Biotechnology Strategy Online, http://strategis.ic.gc.ca/SSG/bh00127e.html

Canadian Food Inspection Agency (CFIA), part of Health Canada

- Office of Biotechnology, http://www.inspection.gc.ca/english/ppc/biotech/bioteche.shtml
- Plant Health and Production Division, Plant Biosafety Office, http://www.inspection.gc.ca/english/plaveg/pbo/pbobbve.shtml

Convention on Biological Diversity (CBD)

- Cartagena Protocol on Biosafety, Biosafety Clearing-House (BCH), http://www.biodiv.org/bch

CSIRO Australia (Australia's Commonwealth Scientific and Industrial Research Organisation)

- Gene Technology in Australia, http://genetech.csiro.au/

European Commission, Joint Research Centre (JRC): http://www.jrc.org/

International Centre for Genetic Engineering and Biotechnology (ICGEB)

- Biosafety Web Pages, http://www.icgeb.trieste.it/~bsafesrv/

Organisation for Economic Co-operation and Development (OECD)

- BioTrack Online (Biotechnology Regulatory Developments in OECD Member Countries), http://www.oecd.org/ehs/country.htm
- Database of Field Trials, http://www.olis.oecd.org/biotrack.nsf

U.K. Department for Environment, Food & Rural Affairs, Advisory Committee on Releases to the Environment (ACRE): http://defra.gov.uk/environment/acre/index.htm

U.K. Department of Trade and Industry (DTI), Biotechnology and Pharmaceuticals

- BioGuide (guide to biotechnology support and regulations in the U.K.), http://dtiinfo1.dti.gov.uk/sectors/biotechnology.htm

U.N. Environment Programme (UNEP), International Register on Biosafety (IRB): http://www.unep.org/unep/program/natres/biodiv/irb

U.N. Food & Agriculture Organization, Technical Cooperation Network on Plant Biotechnology in Latin America and the Caribbean (REDBIO/FAO): http://rlc.fao.org/redes/redbio/html/home.htm

U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS)

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- United States Regulatory Oversight in Biotechnology, http://www.aphis.usda.gov/biotech/OECD/usregs.htm

U.S. Department of Agriculture (USDA), Cooperative State Research, Education, and Extension Service (CSREES), Agricultural Research Service (ARS)

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U.S. Department of Agriculture (USDA), Cooperative State Research, Education, and Extension Service (CSREES), Agricultural Research Service (ARS), National Agricultural Library (NAL)

- Biotechnology Information Resource (BIC), http://www.nal.usda.gov/bic/

U.S. Department of Agriculture (USDA), Cooperative State Research, Education, and Extension (CSREES), Agricultural Research Service (ARS), Plant Genome Research Program

- GrainGenes (database for small grains and sugarcane), http://wheat.pw.usda.gov/index frame.html

U.S. Department of Health and Human Services (HHS), National Institutes of Health (NIH)

- Bioethics Resources on the Web (including biotechnology), http://www.nih.gov/sigs/bioethics/

U.S. Department of State, Office of International Information Programs

- Biotechnology: Food Security and Safety (thematic issue of *Economic Perspectives* Vol. 4, No. 4, October 1999), http://www.usinfo.state.gov/journals/ites/1099/ijee/bio-toc.htm
- Global Issues: Biotechnology, http://www.usinfo.state.gov/topical/global/biotech

U.S. Environmental Protection Agency (EPA), Office of Pollution Prevention and Toxics

- Toxic Substances Control Act (TSCA) Biotechnology Program, http://www.epa.gov/opptintr/biotech/

U.S. Food and Drug Administration (FDA), Center for Food Safety and Applied Nutrition (CFSAN)

- Biotechnology information, http://vm.cfsan.fda.gov/~lrd/biotechm.html

Nonprofit Biotechnology Entities

AgBioTechNet (Online Service for Agricultural Biotechnology, from CABI Publishing, with support from Agricultural Biotechnology Support Project): http://www.agbiotechnet.com/

Agricultural Biotechnology Support Project (ABSP), formerly Agricultural Biotechnology for Sustainable Productivity project (USAID-funded project awarded to Michigan State University's Institute of International Agriculture): http://www.iia.msu.edu/absp/

Bioline International

- publishes *BioSafety Journal*, http://www.bioline.bdt.org.br/by

Consultative Group for International Agricultural Research (CGIAR) Research Centers: http://www.cgiar.org:80/centers.htm

European Federation of Biotechnology (EFB): http://efbweb.org/

- Agri-Biotechnology Section, http://www.agbiotech.org/pages/efb/home.html
- EFB Task Group on Public Perceptions of Biotechnology, http://www.kluyver.stm.tudelft.nl/efb/tgppb/main.htm

Illinois-Missouri Biotechnology Alliance (IMBA): http://www.ssu.missouri.edu/imba/

- publishes *AgBioForum* magazine, http://www.agbioforum.missouri.edu/

Information Service for National Agricultural Research (ISNAR)

- ISNAR Biotechnology Service (IBS), supported by Government of The Netherlands, Government of Switzerland, Government of Japan, and others, http://www.cgiar.org/isnar/ibs.htm

Information Systems for Biotechnology (ISB), part of the National Biological Impact Assessment Program (NBIAP) and administered by USDA/CSREES

- International Field Test Sources, http://www.isb.vt.edu/cfdocs/globalfieldtests.cfm
- publishes *ISB News Report*, http://www.isb.vt.edu

International Food Information Council (IFIC)

- Food Biotechnology information, http://ific.org/food/biotechnology.vtml

International Service for the Acquisition of Agri-Biotech Applications (ISAAA): http://www.isaaa.org

National Agricultural Biotechnology Council (NABC), a consortium of 30 leading agricultural research and teaching universities in the U.S. and Canada: http://www.cals.cornell.edu/extension/nabc/

National Biotechnology Information Facility (NBIF), based at New Mexico State University: http://www.nbif.org

University of Guelph, Department of Plant Agriculture (Canada)

- Food Safety Network, Genetically Engineered Food/Crops, http://www.plant.uoguelph.ca/safefood/

Nonprofit Consumer and Environmental Entities

Ag BioTech InfoNet (sponsored by a consortium of scientific, environmental, and consumer organizations): http://www.biotech-info.net

The Edmonds Institute: http://www.edmonds-institute.org

Genetic Resources Action International (GRAIN): http://www.grain.org/front.cfm

Greenpeace International

- Genetic Engineering information, http://www.greenpeace.org/~geneng/gehome.htm

Rural Advancement Foundation International (RAFI): http://www.rafi.org/

Union of Concerned Scientists (UCS), Food and Environment Program

- Biotechnology information, http://www.ucsusa.org/food/0biotechnology.html
- publishes *FoodWeb* (formerly *Gene Exchange*), http://www.ucsusa.org/agriculture/foodweb.html

Industry Trade Associations and For-profit Entities

AGBIOS (Agriculture & Biotechnology Strategies, Canada): http://www.agbios.com/

Agricultural Groups Concerned about Resources and the Environment (AGCare), representing producer groups in Ontario, Canada: http://www.agcare.org

American Crop Protection Association (ACPA)

- Issues: Agricultural biotechnology information, http://www.acpa.org/

BioAbility (formerly Institute for Biotechnology Information, IBI): http://www.biotechinfo.com
BIOTECanada: http://www.biotech.ca/EN/index.html

Biotechnology Industry Organization (BIO): http://www.bio.org

Council for Biotechnology Information (CBI): http://www.whybiotech.com/en/default.asp

Food Biotechnology Communications Network (FBCN) (Canada): http://www.foodbiotech.org

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The Electronic version of **Genetic Engineering of Crop Plants** is located at:
HTML
http://www.attra.org/attra-pub/geneticeng.html
PDF
http://www.attra.org/attra-pub/PDF/geneticeng.pdf

APPENDIX 1

GMO Issues Facing Indiana Farmers in 2001

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The global debate over genetically modified organisms, specifically transgenic crop varieties, shows little evidence of slowing down. Whether you favor transgenic plant breeding or not, the short term effects on market acceptance for transgenic crops in general are impacting corn and soybean farmers directly. You only have to look at the uproar caused by the contamination of last year's commercial corn and seed corn production by the Cry9C Bt transgene (approved for animal consumption and industrial use but not human consumption) to realize how quickly the global debate can hit home.

As Indiana farmers prepare for the 2001 growing season, what can they expect? Will there be any more unexpected "red flags" regarding the acceptance of currently available transgenic crop varieties? What can farmers do to best minimize the transgenic market risk to their farming operations?

First of all, recognize that NONE of the currently available insect-resistant or herbicide-tolerant corn or soybean varieties are CRITICAL for the success of Indiana farmers.

- European corn borer, the corn pest targeted by Bt corn hybrids, occurs infrequently enough and at sufficiently low levels that the use of Bt hybrids is not economical for most Indiana corn growing situations (Hyde et al. 1998). Such hybrids are best suited to extremely early or late corn plantings where the risk of injury to the corn borer is greatest.
- The glyphosate tolerant soybean technology is a very handy weed control tool and often lowers total weed control costs, but cannot be considered critically important for the success of soybean production in Indiana. The same holds true for glyphosate tolerant and glufosinate tolerant corn hybrids.

Because these transgenic crop traits are NOT CRITICAL for the success of Indiana farmers, the choice of whether to grow them or not depends primarily on the farmer's assessment of the uncertainty of market acceptance for such products and/or the available seed supply of alternative non-transgenic varieties.

What if a farmer elects not to use transgenic crop varieties, but is concerned about the risk of contamination of his/her grain by transgenic grain? In other words, what are the possible means by which one can end up with transgenic grain interspersed with that produced from a non-transgenic variety?

Seed Supply. Seed producers face the same challenges of producing pure non-transgenic crop seed as do commercial grain producers. Consequently, most have been reluctant to assure 100 % "pure" seed relative to transgene contamination.

In late December, the USDA strongly recommended that seed companies sample and test all of their 2001 seed corn lots and all seed parent lines for the presence of the Cry9C Bt transgene because of the hue and cry raised last fall with the discovery of this genetic material in corn flour and products made from corn flour. Any seed lot testing positive for Cry9C will be channeled into feed or non-food industrial use. USDA also recommended that seed companies provide the verification information to customers when customers ask for it.

The seed industry has responded to this demand by supposedly testing all seed lots for the presence of the Cry9C Bt transgene. Unfortunately, seed companies cannot guarantee zero presence of Cry9C in any seed lot. The currently available quantitative tests, when used with appropriate sampling intensities, are capable of detecting the presence of the Cry9C protein at the minimum detectable level of no less than about 0.2 % with a 99 % probability.

Every corn grower needs to take reasonable precautions to avoid introducing the Cry9C Bt transgene into the 2001 corn crop. At a minimum, corn farmers should "verify before they buy" and insist on receiving the results from the USDA-recommended seed testing plan for the Cry9C Bt transgene. Ask for the results in writing, keep this documentation for your records, and help to assure the integrity of the 2001 harvest. Additionally, consider saving a sample of seed from each lot of supposed non-transgenic hybrid or variety for purity retesting in the event that you need to re-verify the non-transgenic integrity of a particular seed lot.

At a maximum, ask for written assurances for ANY transgene contamination in any non-transgenic corn or soybean variety. Some companies have taken the extra steps to test for any transgene contamination in their non-transgenic hybrid seed lots and are making this information available to their customers.

Previous Crop & Variety. Because of the risk of transgenic volunteer corn, any field planted to a transgenic variety in 2000 (especially the Cry9C Bt transgene) should not be planted to corn again in 2001. Similarly, be sure to prevent any such volunteer corn in this year's soybean fields from setting seed.

Planting Operation. Let's say that a farmer has obtained a "pure" supply of non-transgenic seed corn or soybean, but will also be planting some transgenic varieties in 2001. Obviously, then, there will be some potential for seed contamination during the planting operation. The best advice here is to plant the non-transgenic seed lots first, followed by the transgenic varieties. In this way, any seed carrying over from one seed lot to another in the planter will be from non-transgenic to transgenic and not the other direction.

Pollen Drift Control. Corn is a cross-pollinating plant species, meaning that pollen freely moves with the wind throughout a corn field and, to a limited degree, outside of the field during the active pollination period. While recent research on the extent of pollen drift strongly suggests that the majority of corn pollen from a field lands within a very short distance from the field, some small percent of pollen will travel a quarter of a mile or further and still be viable. Consequently, pollen drift represents a means of transgene contamination for farmers growing non-transgenic hybrids adjacent to fields of transgenic hybrids.

Communication with neighbors is an important aspect of pollen drift awareness. Farmers should find out what corn hybrids will be planted adjacent to their fields of non-transgenic corn, and document the hybrid seed lot information and planting dates. In Indiana, the risk of pollen drift is greatest from fields of corn planted to the southwest of the field in question because of the direction of the prevailing winds in mid-summer. Taking the time to note the dates of pollen shed in your field and adjacent fields will help you determine the relative risk of pollen drift.

The risk of pollen drift from neighboring transgenic corn fields may require the harvesting and segregation of a certain amount of corn around the perimeters of a non-transgenic field, certainly no less than 660 feet from the field edge. Corn harvested from those buffer strips should be fed on the farm, or channeled to elevators willing to accept transgenic corn.

Harvest Operation. Combines should be super cleaned prior to the start of grain harvest to minimize the risk of any leftover grain from 2000 in the machine. If non-transgenic and transgenic varieties are grown on the same farm, then the sequence of harvesting those fields should follow the FIF-FOF (First-In-Field, First-Off-Field) principle. This means that non-transgenic varieties planted in the field first should be harvested before transgenic ones to avoid transgenic grain commingling with non-transgenic grain from the nooks and crannies of the combine.

Handling, Storage & Transport. All grain transport vehicles (trucks, wagons, trailers, grain carts), all grain handling equipment (augers, legs, pits, wet holding bins, dryers) and all grain storage facilities should be super cleaned prior to the start of grain harvest. By following the FIF-FOF principle during harvesting, the post-harvest operations will benefit because non-transgenic varieties can be received, dried and transferred to storage ahead of transgenic varieties. Obviously, transgenic and non-transgenic grain should be stored separately on-farm to avoid grain commingling, and to take advantage of potential premiums for identity-preserved grains in the market place.

Assuming that transgenic grain was put into storage last, then emptying storage facilities for transport to market should begin with the transgenic grain in order to avoid an extra cleaning step, and thus, reduce the chance of contamination. However, given that this strategy will depend on a farmer's marketing plan, all grain transport vehicles and grain handling equipment should be super cleaned prior to every time that non-transgenic grain load-out follows transgenic load-out in order to avoid commingling of grain leftover from the previous handling operation.

Guidelines for Corn, 2001:

- Expect little or no economic benefit from planting approved Bt corn varieties in Indiana.

- Make sure seed corn is certified "clean" for StarLink™ according to the USDA test protocol. Obtain a written verification from the seed company.

- Avoid planting glyphosate tolerant corn. Remember that glyphosate tolerant corn hybrids are approved only in the U.S. and Japan, but not elsewhere around the globe. No quick test kits currently exist for this transgene and no tolerance levels have been established. Even though some grain buyers are assuring farmers that they will purchase grain from these hybrids, farmers bear the sole risk for rejection at the first point of sale should buying policies change at any time in the future.

- Recognize that grain elevators would prefer not to accept any transgenic corn that does not have full approval for the global market place and, subsequently, may change their stance on acceptance of such grain this fall.

  Be aware that Monsanto has established a channeling program for glyphosate tolerant corn. When buying glyphosate tolerant corn seed, farmers commit in writing to market the grain from these hybrids only through approved channels. We urge all farmers to live up to this commitment! Approved channels are over 2000 U.S. elevators that are willing to buy non-EU approved grains. The American Seed Trade Association maintains an online database of "…grain handling facilities that have indicated a willingness to purchase, receive, and handle genetically enhanced corn products that have full U.S. registration for food and feed use, but are not yet approved for import into the European Union." The Web address for the ASTA database is <http://asta.farmprogress.com/>.

- Recognize that grain processors have urged producers only to plant varieties that have full approval for the global market place and, subsequently, will unlikely accept any transgenic corn this fall.

  Be aware that Monsanto, as part of their channeling program, is also establishing a database of every farmer who purchases glyphosate tolerant corn seed. Although they have committed not to reveal names and addresses, they will work with any inquiring processor and reveal to them how many acres of glyphosate tolerant corn were planted in the areas from where they plan to purchase corn. For any area that a processor raises concern, Monsanto will contact those farmers and remind them to market their corn only through approved channels after harvest. We urge processors to inquire about glyphosate tolerant acres and urge all farmers to comply with the channeling program!

Guidelines for Soybean, 2001:

- Non-transgenic soybean seed supplies are limited.
- Some grain buyers have specialty contracts for non-transgenic soybeans.
- Grain buyers and processors will be buying glyphosate tolerant soybeans.
- Foreign buyers have been buying and appear to continue to be willing to buy glyphosate tolerant soybeans (and meal).

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For other information about corn, take a look at the Corn Growers Guidebook

Published at the Chat 'n Chew Cafe, 12 March 2001 (rev. 20 March) at: http://www.kingcorn.org/news/articles.01/GMO_Issues-0312.html

APPENDIX 2

Wheat Industry Is Cautious on Biotech Introduction

By Bill Hord
World-Herald via AgriBiz.Com
May 29, 2001

The word is out in the food industry—don't mess up when it comes to wheat. Wheat is the world's favorite crop. It is bread, pasta, apple pie crust, cookies and pastry. Be careful.

The U.S. wheat industry began waving the caution flag more than a year ago as some consumers around the world rebelled against food that contains genetically manipulated soybeans or corn.

Now even Monsanto Inc., a company that is a leader in inserting new genes in plants, has gotten the word about wheat.

"We are breaking new ground, and we have to proceed carefully," said Mark Buckingham, a Monsanto spokesman at the company's headquarters in St. Louis.

Monsanto introduced the first GMO (genetically modified organism) for a major U.S. crop—soybeans—in 1996. Now, nearly two-thirds of the U.S. soybean crop is made up of GMOs, up from 54 percent last year.

But wheat is different. Forty-eight percent of all U.S. wheat is exported, compared to 20 percent for corn and 8 percent for soybeans. And nearly half of all wheat exports go to countries, such as Japan and European nations, that have a real sensitivity about GMOs. To lose foreign customers would be an economic disaster to the U.S. wheat industry.

The concern is so great that the state legislature of North Dakota considered a proposal in recent months to put a moratorium on the growing of GMO wheat. In the end, the legislation was amended to require a study of the issue instead.

Monsanto is expected to announce next week the formation of a wheat-industry committee to advise it on how and when to put wheat genetics on the market, including the current front-runner—Roundup Ready wheat.

As it does in corn and soybeans, the Roundup Ready gene would allow farmers to use the company's potent Roundup herbicide to kill weeds without affecting the wheat plant. Monsanto expects to have the new plant ready for farmers by 2005 and possibly as early as 2003.

Many farmers would welcome a wheat plant that would allow them to use weed killers or would ward off wheat diseases.

"It would make my life a lot easier," said Dan Hughes, a Grant, Neb., farmer. "But it doesn't do me any good if I can't sell the wheat."

Wheat is Nebraska's third largest crop behind corn and soybeans, with most of the state's wheat production coming from the drier regions of the south and southwest. In 1999, the state's farmers exported $119 million worth of their $186 million wheat crop to foreign markets. Kansas was the nation's leader with $805 million worth of wheat exports.

Very little wheat is grown in Iowa, where higher annual rainfalls favor corn and soybeans, two crops that do not do as well as wheat in drier climates.

Even as the industry frets about stability in wheat markets, researchers all over the country are testing plots.

The University of Nebraska-Lincoln is testing GMO wheat designed to resist diseases, increase seed size and improve protein or starch quality.

"I truly believe transgenic wheat will be sold in the future," said Steve Baenziger, a wheat breeder at UNL. Tom Clemente, manager of plant genetics research at UNL's Beadle Center, said, "These products (being tested at UNL) wouldn't be in growers' hands for years to come."

Monsanto's Buckingham said researchers are also testing wheat plants that would improve the quality of frozen dough or make it possible for people with a physical intolerance for wheat gluten to eat wheat products.

"There is a lot of potential down the road for very direct consumer benefits," Buckingham said.

Wheat industry leaders say they have learned their lesson from StarLink, the cuss word in plant genetics circles.

"I hate to even mention the word," said Darrell Hanavan, chairman of a joint wheat-industry committee on biotechnology and executive director of the Colorado Wheat Administrative Committee.

StarLink was a corn plant genetically designed to release a protein that would kill corn borers. Although it was approved only as a livestock feed pending further study of whether it would aggravate allergies, the corn found its way into taco shells.

The result was upheaval in the grain markets, including rejection of some U.S. corn shipments by Japan. There is now universal agreement in the food industry that no new seed should be sold until it has full government approval for human consumption.

Last month, Japan informed Hanavan and a team of U.S. wheat industry leaders that it would take its business elsewhere if U.S. farmers begin growing GMO wheat.

"Essentially, they said that at this point in time there is no consumer acceptance of biotech products," Hanavan said.

In an unprecedented concession, Monsanto has committed to withholding GMO wheat from the market until Japan gives its approval. Wheat industry leaders have determined that two other things are needed before GMO wheat seeds should be sold to farmers, both of which are lessons learned from StarLink.

First, says Hanavan, the world needs to agree on a tolerance standard. StarLink's problems were multiplied because the standard was zero tolerance, meaning that a trace of StarLink was enough to have it turned away from food use even though a trace was hardly considered problematic by scientists.

Second, wheat growers want a reliable system for keeping GMO wheat separated from conventional wheat. No such system existed when the Environmental Protection Agency decided StarLink could be grown for livestock feed but not for human food.

Hanavan said wheat industry organizations want to make progress toward a day when biotech wheat can have a place in the food chain without jeopardizing wheat sales around the world.

"Our whole policy position is based on the premise that we support biotechnology," Hanavan said. "It holds great promise for the future, but our concern is with market acceptance."

APPENDIX 3

On the Implications of the Percy Schmeiser Decision

By E. Ann Clark, Ph.D.
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The Crime of Percy Schmeiser

Let us first be clear on the crime for which Saskatchewan farmer Percy Schmeiser was found guilty. He was found guilty of a) having Monsanto genetics on his land, and b) not advising Monsanto to come and fetch it. He was not found guilty of brownbagging—obtaining the seed fraudulently. Indeed, all such allegations were dropped at the actual hearing, due to lack of evidence.

Regardless, in his 29 March 2001 decision [http://www.fct-cf.gc.ca (click on bulletins)], Judge W. Andrew MacKay made it clear that how it got there didn't matter anyway. The guilt was the same. Specifically, to quote MacKay, "the source of the Roundup resistant canola...is really not significant for the resolution of the issue of infringement...."

It also didn't matter that Schmeiser did not benefit—at all—from the RR seed. In order to derive any economic benefit from growing Roundup Ready (RR) seed, you'd either have to sell it as seed, or spray Roundup. He did neither. He sold the crop as grain, not as seed, and he didn't spray Roundup. He acknowledges spraying Roundup around his telephone poles, a standard practice, which first alerted him in 1997 to the contamination in his field because some of the plants didn't die. Then, in typical farmer fashion, he got out his sprayer and made a couple of passes leading away from the road to see how far the contamination reached: the total sprayed area was 3 acres out of the hundreds of acres sown in 1997. None of these points are disputed. No one—including Monsanto—argued that Schmeiser actually benefitted—or even intended to benefit—from growing a crop contaminated with RR plants. But it didn't matter. He was guilty nonetheless, and fined $15/acre x 1030 acres. Monsanto also seeks the value of his crop: $105,000 (Canadian) plus $25,000 for punitive and exemplary damages.

He also lost the improved genetics resulting from his lifelong practice of saving his own seed to produce his own tailor-made variety of canola, as the crop was confiscated. The harm that has been done to Percy and Louise Schmeiser, now in their 70s, is grievous. But of even greater concern is how this incomprehensible decision will affect all western Canadian farmers regardless of whether they even grow canola, let alone genetically modified (GM) canola.

The Problem(s) with Canola

Canola is a relatively primitive crop, and as such, retains many of the characteristics of a wild species. Unlike corn and wheat, which have been domesticated by over 10,000 generations of breeding, canola pods mature unevenly, obliging farmers to cut and place the crop in windrows to allow the green seed to dry prior to combining. The dry pods also shatter upon maturity, dropping a fraction of the mature seed to the ground. The seed retains dormancy, meaning that especially under the reduced or no-till conditions favored in the prairies, the seed can remain dormant for 6–10 years, depending on the type of cultivar—Polish or Argentine—and the seed can germinate anytime in the season,not just in the spring prior to seeding.

Further, because the seed is very small, round, and smooth, it travels readily in the wind. It is not uncommon for windrowed canola to be picked up and blown over adjoining fields. Seed is known to be dispersed by haul trucks—either blown out the top if uncovered or falling off the exterior if not filled tidily. Schmeiser's contaminated fields are to the east side of a major haul road leading to Bruno, Saskatchewan, and the prevailing wind direction is west to east. The initial samples used by Monsanto to charge Schmeiser were actually taken from the roadside—not the sown fields.

Although canola is primarily a self-pollinating species, outcrossing is in the range of 20–30%, and canola pollen can move long distances, several km at least, primarily via insect pollinators. The required isolation distance for hybrid canola seed is 800 m. Who is it that has to absorb the cost of installing an 800 m buffer between GM and non-GM crops on neighboring farms? Pollen has always moved—it did not start with genetic modification. But this is the first time we've called it genetic pollution, because the genes that move are proprietary.

To put these numbers into perspective, Alberta Agriculture has calculated that even at 0.2% outcrossing (with a neighbor's RR canola, for example), a crop yielding 25 bu/acre with 3% shattering losses would deposit 10,000 outcrossed seeds/acre, or 4 outcrossed seeds per square meter (http://www.agric.gov.ab.ca/crops/canola/outcrossing.html). And that is just the genetic pollution from a single season. The lengthy dormancy interval of canola allows the soil seed bank of contaminated seed to accumulate in the soil with each successive year's addition.

Land can be contaminated with proprietary seed in other ways. If you intentionally planted RR canola [or any other herbicide tolerant (HT) canola variety], shattered RR seed would contaminate your soil next year anyway, and the next, and the next. Emergence of volunteer canola in subsequent crops is nothing new in western Canada—but what is new is that the volunteer plants bear proprietary genes and are tolerant to one or more common herbicides.

You can also bring RR canola into your land inadvertently, as an unavoidable contaminant in your sown crop. Cross contamination of seed crops with GM seed is now so pervasive that seed companies will no longer guarantee them 100% GM-free, even in the seed they sell to farmers, for any field crop that has been subject to genetic modification.

In the aggregate, these arguments explain the widespread occurrence of RR canola growing in places where it was never sown, and even where no canola has been sown, in western Canada.

The impossibility of reproductive isolation—both on-farm and post harvest—is nowhere better illustrated than the recent occurrence of contamination within Monsanto's own RR Quest canola. Seed with an unapproved RR gene was found to contaminate bags carrying seed with the approved RR gene, obliging the urgent recall of thousands of bags of seed, some of which was already on-farm and being sown. This is just the latest example of cross contamination within the seed trade itself, of which StarLink contamination in the corn to be sown in 2001 is perhaps the best known example.

How then can farmers be held accountable for something that the seed trade itself cannot do? Well, they can't, and even Monsanto knows it. So, Monsanto's position—which the judge inexplicably accepted—is that all the farmer has to do is call them up and they'll come out and deal with it. No matter how the proprietary genes got there, the judge held that the farmer is accountable for it, and they are obliged to inform Monsanto about it—or risk the fate of Schmeiser.

Between a Rock and a Hard Place

Now, this is an interesting conundrum. Put yourself in the position of a farmer. To appreciate the gravity of the choice on-offer, you need to appreciate how Monsanto's hired investigators operate. They come to the door, advise you that you're suspected of brown-bagging, and offer you a letter stipulating what you must pay to avoid being formally prosecuted. Should you choose to pay the fee, you are also obliged to sign a letter which states that by signing, you agree to remain silent and tell no one about what has happened, or face further prosecution.
Let's say you know that you have one or more of Roundup Ready, Liberty Link, Navigator/Compas or SMART canola (tolerant to the herbicides glyphosate, glufosinate ammonium, bromoxynil, or some ALS inhibitors,

respectively) on your land. You know this because, like Schmeiser, the plants didn't die when you used the corresponding herbicide. So, what do you do?

Do you call up the company (Monsanto, Aventis, Aventis, and/or Pioneer, respectively), inform them that you have infringed upon their respective patent(s), and ask them to come out for a visit—then hope they arrive with a sprayer and not a subpoena? If the latter, no one will ever know, will they? Or do you wait for a neighbor to report you for suspected brownbagging, using the anonymous hotline set up by Monsanto for that purpose?

If the respective company(-ies) come out and actually do spray out the offending plants, do you call them back again a few weeks later, when late germinating canola has emerged in your wheat or pea crop? How is it that they are going to eradicate these late germinating, potentially seed-bearing HT plants, in your established crop? Will they compensate you for damage done to your crop in the process, or from spray drift (a particular problem with the herbicide of choice, 2,4-D) to your adjoining crops, or your neighbor's?

What if it was canola you were intending to plant in the contaminated field? You know that you will not be able to distinguish volunteer HT canola from whatever canola you've planted. You know that volunteer HT canola will set seed and shatter, just like your sown canola, re-contaminating the land with patent-infringing seed. By definition, if you grow canola on land known to have HT canola in the seed bank, your problems will necessarily amplify over time. Where you had one HT plant this year, you could have dozens next year. So, do you abstain from growing canola entirely? For how long, given that fresh contamination can occur annually?

Or do you take responsibility yourself for eliminating the proprietary plants? Do you adjust your crop rotation, your herbicide expenditures—and your bottom line—to cope with contamination that you did not want and could not stop, and that will reoccur annually so long as neighbors choose to grow HT canola?

Like the StarLink debacle which continues to haunt US corn growers, marketers, consumers, government officials, and the seed trade itself, the guilty verdict in the case of Percy Schmeiser illustrates some of the shortcomings of applying GM technology to field crop agriculture. Far from making food cheaper, GM technology will necessarily make food more expensive—and particularly, but not solely—for those who have chosen not to grow GM crops.

Why should non-GM growers be obliged to adjust their rotation and herbicide schedules and field design in order to protect their own crops from contamination from neighboring GM crops? Why should non-GM growers have to absorb costs of coping with gene flow that is unwanted, involuntary, and unavoidable—or face prosecution? Why should those who have managed their crop specifically for the high-premium GM-free market be forced to lose the premium because of contamination from neighboring land? Why should any farmer be forced to accept GM contamination in the seed they sow on their own land?

Why should taxpayers be obliged to support the mushrooming government infrastructure needed to monitor, regulate, and negotiate to keep GM crops in the marketplace, and the virtually endless costs of recalling contaminated seed and food products from the market? Why should consumers have to pay more for food that is worth no more (and arguably, less to them) because the costs of dealing with unwanted GM both on the farm and in the marketplace must, necessarily, be passed on to the consumer?

Why should all growers be penalized by plummeting crop prices incurred because a minority of growers chose to grow GM, causing traditional clients to refuse to buy GM-contaminated grain and instead to patronize off-shore sources? Since when do importing countries have to buy GM grains, just because we want to grow them? What happens when the traits that move are not HT, but vaccines, pharmaceuticals, plastics, and industrial enzymes? When is the Canadian government going to stop promoting the commercialization of a technology which has so clearly been released prematurely into the marketplace, and which so clearly externalizes its true costs of production involuntarily and unavoidably to its own citizens?

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This article first appeared in the Genetics Society of Canada Bulletin, June 2001. It is reprinted here from Dr. Clark's website at <http://www.plant.uoguelph.ca/faculty/eclark/> *where other talks and articles are posted.*

APPENDIX 4

A History of Intellectual Property Rights (IPRs)

Appendix 2 from
Agricultural Biotechnology:
Critical Issues and Recommended Responses from the Land-Grant Universities

A report to the Experiment Station Committee on Organization and Policy (ESCOP) and the Extension Committee on Organization and Policy (ECOP) January 21, 2000

Efforts to secure legal protection for inventions related to living organisms while accounting for their self-replicating and natural origin started several decades ago. Improved plant cultivars, when propagated as clones, have been awarded protection since 1930 under the Plant Patent Act. Furthermore, Plant Breeders' Rights (PBRs) are patent-like rights for cultivated plants. PBRs were organized in 1961 under the International Union for Protection of New Varieties (UPOV), an international convention. The US adopted PBRs in 1970.

In 1980 the Supreme Court in the significant Chakrabarty decision extended the scope of utility patents to living organisms. Specific extension to plants was decided by the patent office in 1985 (Ex parte Hibberd) and to animals in 1987 (Ex parte Allen). Utility patent claims require demonstration of novelty, utility, and non-obviousness. By comparison, the tests for PBRs certificates are uniformity, stability, and distinctiveness.

PBRs and utility patents differ in some significant respects. PBRs make allowances for farmers' rights (farmer saved seed) and include a research exemption for the use of protected material in the development of new varieties. PBRs also apply to whole plants or propagating material. Typically they do not protect individual and unique characteristics of a protected variety. Accordingly, they provide no effective protection for biotechnology. Any singular bioengineered trait (e.g., a gene) can be legally copied and transferred to another distinct variety.

IPRs for living organisms are national rights and vary substantially from one country to another, both in coverage and enforcement. Patent rights for living organisms continue to be hazy in the European Union, and many developing countries explicitly exclude plants and animals from patent or patent-like protection. The 1993 Uruguay Round of the GATT agreement changed this balance by recognizing that exports of industrialized countries tend to be technology-rich. As such, absence of IPRs protection in certain regions acts as a trade barrier. The Trade Related Aspects of IPRs (TRIPS) addition to the GATT agreement created a framework for increased standardization of IPRs for plants and animals around the world and the adoption of a minimum standard, in most cases PBRs.

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