Genetically Engineered Foods

#11 in a series

Environmental Safety of Genetically Engineered Crops

A Series from Cornell Cooperative Extension's Genetically Engineered Organisms Public Issues Education (GEO-PIE) Project

SEVERAL ENVIRONMENTAL SAFETY ISSUES ARE ASSOCIATED WITH GENETICALLY ENGINEERED (GE) CROPS. THIS FACT SHEET EXPLORES SOME OF THE MORE COMMONLY DISCUSSED ISSUES RELATED TO THE ENVIRONMENTAL IMPACT OF GE CROPS.

U.S. Regulation of the Environmental Safety of GE Crops

Two U.S. agencies are responsible for regulating the environmental impact of GE crops: the Department of Agriculture (USDA) and the Environmental Protection Agency (EPA). The Animal and Plant Health Inspection Service (APHIS), a subunit of the USDA, is responsible for most issues related to the environmental release of the new crops. The EPA regulates the environmental safety of GE crops that have pesticide-like properties.

For more information about the regulation of GE crops, see GEO-PIE fact sheet 9: *U.S. Safety Regulation of Genetically Engineered Crops*.

Pesticide Use and GE Crops

One frequently cited benefit of GE crop plants is that they might help reduce pesticide use.

Many of the synthetic pesticides used in agriculture are now known to be environmentally persistent and toxic to humans, animals, and other fauna. The EPA is currently reevaluating the safety of many of these chemicals, and some of the more toxic ones may be greatly limited or even banned in coming years. An increasing effort is being made to develop pesticides that are less toxic and less persistent and to explore alternative ways to reduce the use of pesticides in agriculture such as integrated pest management and organic farming.

In theory, plants genetically engineered to be resistant to insects could reduce the use of insecticides in agriculture-- a GE plant with its own built-in insect resistance might no longer need to be sprayed with the insecticide normally used to control the insect pest. Further, if a GE crop with herbicide-resistance allowed the farmer to apply a single herbicide rather than several different ones, this might also lead to a reduction in pesticide use. The actual degree of pesticide reductions, however, can vary dramatically among GE crops-- in some cases significant decreases have occurred, in others none at all, and at least one may increase pesticide use.

Insect resistant GE plants

Bt corn, one of the most widely grown GE insect-resistant plants, was engineered to be resistant to the European corn borer (ECB). The ECB is notoriously difficult to control with insecticides because it bores into the corn stalk where the chemical can't reach it. For this reason, and because ECB outbreaks are extremely variable (thus, spraying is not routine), less than 5 percent of U.S. Corn Belt corn acres are actually sprayed for the pest. Additionally, the insecticides used against the ECB are also used to control other insect pests-- to which *Bt* trait does not provide resistance-- and would be applied regardless of ECB. As a result, reductions of insecticide use on field corn have been minimal or insignificant.

Bt cotton, which was engineered to resist three major cotton pests, now represents over 50 percent of U.S. cotton. USDA data document a large decrease in application of the insecticides used to control these insects. Compared to 1995 (when no *Bt* cotton was grown), the use of these insecticides dropped 10 and 14 percent in 1998 and 1999, respectively.

Herbicide resistant plants

"Roundup Ready" soybeans, which were engineered to resist applications of the herbicide glyphosate (Roundup), are grown on more than half of all U.S. soybean acres. On a normal soybean crop, farmers typically apply several different herbicides multiple times in the season to contol the variety of weeds that appear in the field. Because glyphosate is a broad-spectrum herbicide that affects all plants (including normal soybeans), glyphosate-resistant soybeans simplify weed control by allowing one or a few applications of glyphosate to substitute for many herbicides. Not surprisingly, the number of herbicide treatments applied to soybeans has decreased dramatically.

On the other hand, pound for pound, pesticides are not equal in their toxicity and environmental impact. EPA toxicity data suggest that glyphosate may be considerably less toxic and less environmentally persistent than some of the herbicides it is replacing. Thus, if substitution of glyphosate leads to a net herbicide increase, it is extremely difficult to quantify the real impacts of substituting a larger quantity of a more benign herbicide for a smaller quantity of a less benign one.

Herbicide-resistant GE varieties of cotton have also been widely adopted. USDA data suggest there has been a small decline in herbicide application, both in total pounds and in number of applications since 1995, when GE cotton was first grown. Results from one study indicated that some of this reduction may be a result of the adoption of GE varieties, but another study found no significant change in herbicide use associated with adoption of herbicide-tolerant cotton.

Weediness and GE Crops

Regulatory agencies consider whether a new GE crop variety is more likely to behave like a weed than its conventional counterparts.

A weed is usually defined as a plant that is undesirable, unattractive, or troublesome, especially when it is growing where it is not wanted. By that definition, technically *any* plant could be considered to be a weed, as long as it is growing where people don't want it to grow. But some plants are more likely to become weeds than others. There are certain characteristics that make plants more troublesome and much more likely to grow where they are not wanted. “Weedy” plants often show some combination of these traits:

- long-lived seeds that don't all germinate at the same time
- rapid seedling growth
- high tolerance to changes in environment, and ability to grow in different environments
- compete aggressively with other plants
- produce new seeds continuously
- produce a large number of seeds
- can disperse its seeds long distances

Weeds tend to grow well in areas disturbed by man (as opposed to natural habitats), such as gardens, fields, along highways, and in vacant lots.

Most crop plants, however, do not act like weeds. Aside from the occasional "volunteer" plant sprouting in a field from last year's crop, crop plants are rarely grow outside of a farm field. It is conceivable that if, through genetic engineering, a crop plant was inadvertently given one of the "weedy" characters described above, the plant might be more successful at growing outside the confines of an agricultural field. Such changes might include increased seed viability, number, dispersal; reduced seed dormancy; altered plant growth habit, such as an ability to survive winter, produce more generations per year, or produce seeds over a longer time period; and traits that make the plant more aggressively competitive with other weeds.

None of the traits currently engineered into plants appear to alter the plants' ability to overcome their built-in escape barriers. A recent 10-year study of most commercially released GE varieties to date determined that the GE varieties are no more likely to grow outside an agricultural field than their non-GE counterparts. The USDA's Animal and Plant Health Inspection Service (APHIS) treats all new GE plants as potential weeds. APHIS requires developers to observe all experimental GE plants (usually for a few years) in small, controlled test plots and to submit data addressing the potential change in weediness before they are approved for widespread commercial release.

There is an important distinction between increased weediness and increased fitness, however. Fitness is the ability of a plant to respond better to its environmental stresses and to be more successful at making viable seeds. Many of the traits presently genetically engineered into plants do increase the fitness of the plant-- such as resistance to insects, viral disease, and herbicides-- but do not affect the weediness of the plant. *Bt* corn, for example, is much more resistant to certain insects than non-*Bt* corn, but this improvement does not help corn overcome all of the other seed dispersal and growth habit traits that prevent corn plants from spreading out into the wild.

Gene Flow and GE Crops

Along with the tens of thousands of genes in all crop plants, novel genes in GE crops could be transmitted via pollination to non-GE varieties of the same crop or to other closely related plants, creating offspring that express the GE trait.

One concern associated with genetic engineering is "gene flow," the movement of genes from one organism to another. As a part of their normal reproductive cycle, plants transmit their DNA to other compatible plants via pollen. Genes from fields of crop plants can be transmitted by pollination to plants in the same or other fields or sometimes even to other closely related non-crop plants. Like all of the other genes in a crop plant, the novel genes engineered into a GE plant can potentially be transmitted to other nearby related plants, whose offspring will then acquire the new trait of the GE plant.

Two issues are considered when assessing the gene flow risk. First, the likelihood of a plant transmitting its pollen to other plants (the same species or other closely related ones) and the impact, if any, resulting from other plants acquiring the new GE trait.

Risk of gene flow to others of same species

Some small fraction of the pollen of plants that are wind or insect pollinated may travel considerable distances before fertilizing a flower. Examples of these among GE crop plants include corn, canola, squash, and sugarbeets. Pollen from a field of GE corn may fertilize some of the plants in an adjacent field of non-GE corn. This will likely prove to be a problem only for farmers trying to market non-GE crops if the crop is wind or insect pollinated and their nearby neighbors are growing a GE variety of the same crop. Some crops, such as soybeans and tomato, are self-pollinated and do not pose the same level of risk.

Risk of gene flow to other species: crossing the "species barrier"

Some crop plants are able to fertilize the flowers of closely related plant species. These relatives are usually considered weeds and are often found growing near agricultural areas. However, these interfertile weedy relatives normally grow only in the geographical area in which the crop species was originally domesticated. Because most crops grown in the U.S. are no*t* native to the United States, most do not have wild relatives here that they could pollinate. The two most widely-grown GE crops in the U.S., corn (native to Central America) and soybeans (native to Southeast Asia), have no wild relatives in the United States. Rapeseed (canola), widely grown in Canada, does have common wild relatives in North America with which it is interfertile-- a few members of the mustard family.

In early 2000, reports began to appear that a Canadian rapeseed (canola) farmer had identified rapeseed plants (not weedy relatives) growing in his fields that had acquired resistance to *three* different herbicides. This has since become an oft-cited example of the gene-flow problem associated with genetic engineering. Most reports, however, neglect to mention that only two of the three sources of herbicide tolerance had come from GE varieties the farmer was growing. The third came from an herbicide tolerant variety of rapeseed created by conventional plant breeding—suggesting that gene flow is not actually unique GE crops.

Results of Gene Flow

If a non-GE plant acquires a novel gene from a GE crop plant of the same or different species, the seeds resulting from that pollination-- and the plant growing from that seed-- will also express the GE trait. For example, if a weedy relative of rapeseed is pollinated by a rapeseed plant engineered to be resistant to an herbicide, then its offspring will also be resistant to that herbicide. In that case, the herbicide would probably no longer control the weed. Likewise, herbicide-resistant volunteers of crop plants might also prove more difficult to control. The plants resulting from this potential gene transfer are sometimes dubbed "super weeds," but this term is misleading. The resulting plants have no new weed-like traits other than resistance to a single herbicide.

Gene flow from conventional crops

Genes are as likely to move from non-GE crops as they are from GE crops. Most plant species have tens of thousands of genes, and all of these genes in a plant can also be transmitted to related plants. Using conventional plant breeding, varieties of crop plants have been developed which are resistant to insects, viruses, herbicides, are drought-tolerant, have slow-ripening fruit, and possess many traits similar to those added via genetic engineering. The genes controlling these traits in conventionally bred plants may also move to other related plants-- thus presenting similar risks-- and these gene movements are not uncommon.

Impact of GE Crops on Monarch Butterfly Larvae

A 1999 laboratory study suggested that certain GE crops may have an impact on the larvae of Monarch butterflies. Subsequent studies showed that the actual risk in nature is extremely low.

Several varieties of corn and cotton have been genetically engineered to resist attacks from the larvae of Lepidoptera, the insect family that includes moths and butterflies. The larvae of monarch butterflies (and most other butterfly species) do not feed directly on corn or cotton, so USDA regulators initially had no reason to suspect that the GE varieties could cause them harm. A report published in *Nature* in May 1999 suggested that if corn pollen were to blow onto milkweed leaves-- the sole source of food for monarch larvae-- that the larvae could be harmed by inadvertently consuming the pollen. The study demonstrated that monarch larvae, when fed milkweed leaves dusted with genetically engineered corn pollen, had reduced growth rates and were less likely to survive to adulthood.

After the initial finding, the EPA requested researchers to submit data clarifying the actual risk of *Bt*-corn pollen to monarchs in nature. In September 2001, five studies published in *Proceedings of the National Academy of Science* concluded that, despite a substantial overlap in the natural habitat of monarch butterflies and corn-producing regions in the U.S., monarch larvae are very rarely exposed to toxic levels of *Bt*-corn pollen in nature (less than 56 in one million). This impact is particularly insignificant when compared to monarch butterfly exposure to conventional agricultural insecticides.

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