Photo: Greenpeace

Genetically Modified Organisms:

Why All The Controversy?

GMOs can generate substantial benefits for producers and consumers, but resistance to GMOs is likely to continue until questions are resolved concerning their safety for people, animals, and the environment.

by Matthew P. Feldmann, Michael L. Morris and David Hoisington

Why have genetically modified organisms (GMOs) suddenly become a lightning rod for public debate? Proponents of GMOs say that genetic modification of plants and animals is nothing more than the latest in a long series of productivity-enhancing technologies that have helped increase the world's food supply. Opponents counter that GMOs are fundamentally different from naturally occurring organisms — so different that they pose a threat to the character and quality of the food supply. Who is right? We attempt to shed light on the controversy by addressing 10 basic questions about GMOs.

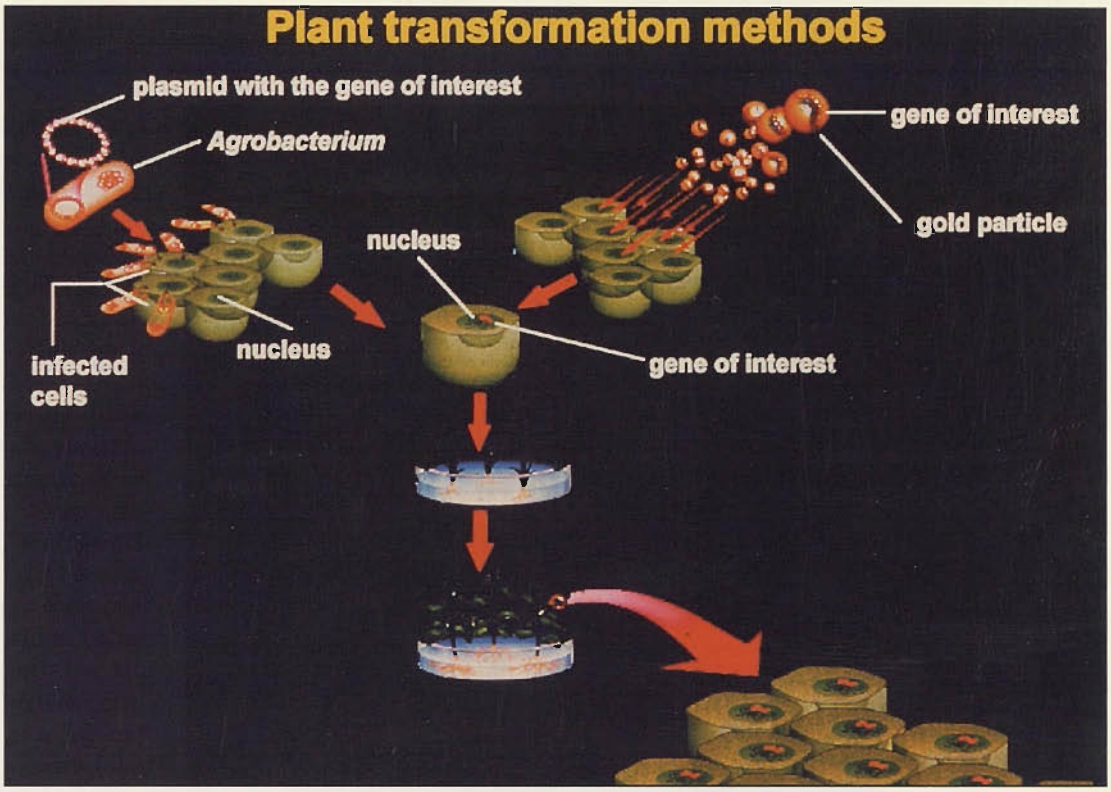
1. What is a GMO?

GMOs are living organisms (plants, animals, bacteria) into which foreign genes have been inserted. The foreign genes come from various sources and change the characteristics of the recipient organism. Genetically modified crops, the focus of this article, are designed to do one of two things: (1) lower farm-level production costs, or (2) enhance product quality.

2. How are GMOs produced?

GMOs are produced through genetic engineering, a process in which genes that yield desirable traits are transferred from one organism to another. Genetic engineering begins with the identification of the gene responsible for the desired trait. After the gene has been identified and isolated, it is inserted into the cell of another organism using one of several techniques. The most widely known technique involves a "gene gun," a device that uses bursts of helium to propel microscopic particles, coated with copies of the gene, directly into the receptor cell. A second common technique uses a bacterium to invade the receptor cell and "plant" some of its DNA along with the foreign gene that carries the desired trait. In either method, the foreign gene is not inserted into every potential receptor cell, so it is necessary to identify cells that have been successfully modified. This is done by inducing the receptor cells to

develop into mature plants, which are then screened to determine whether the foreign gene is present and functioning properly. Plants that have been successfully modified display the desired trait.



Same plant, new traits. Changing the genetic makeup of an organism requires the desired gene to inserted either by bacterium "planting" or by "gene gun" technology.

Photo courtesy of the authors.

3. Why are GMOs so controversial?

Genetic engineering differs from conventional plant and animal breeding because it allows genes to be moved across taxonomic boundaries. With genetic engineering, genes can be transferred not only between closely related organisms (as from a wheat plant to a rice plant), but also between entirely different organisms (perhaps from a fish to a strawberry plant). In conventional breeding, nature imposes limits on genetic recombination by erecting barriers against crossing between biologically distinct organisms. With genetic engineering, these barriers do not always have to be respected, which is why some people consider GMOs to be "unnatural organisms" that violate the laws of nature and are likely to be dangerous.

4. Who produces GMOs?

Most research on transgenics (another term for GMOs) is carried out in industrialized countries, where the leading life-science companies that dominate the global seed industry are investing heavily in genetic engineering of crops. The large multinationals represent only the tip of the industry iceberg, however, as they are supported by hundreds of smaller research firms, specialized equipment manufacturers, and university laboratories.

5. Where are GMOs currently being grown?

Research on genetically modified crops began decades ago, but only recently have products been available for commercial use. In 1990, China became the first country to introduce a genetically modified crop, a virus-resistant tobacco variety. In 1994, a delayed-ripening tomato became the first genetically modified food crop to be grown commercially in the United States. Since then, genetically modified crops have found their way into farmers' fields with increasing frequency. By 1999, transgenic crops covered nearly 100 million acres in the United States, Argentina, Canada, China, Australia, South Africa, Mexico, Spain, France, Portugal, Romania, and Ukraine (James).

6. What are the potential benefits of GMOs?

Most transgenic crops currently being grown feature traits designed to increase farm-level productivity by raising crop yields and reducing input use. Probably the best-known example involves *Bt*, a gene from the soil-borne bacterium *Bacillus thuringiensis* that induces plants to produce a protein that is toxic to insect pests. The resistance conferred by *Bt* can increase yields and reduce the need for chemical pest control. Based on trials conducted in the United States, Koziel, et al., estimate yield gains of up to 8 percent in *Bt* corn. Reduced use of pesticides further increases profits, saving an average of $2.80 to $14.50 per acre in the United States (Carlson, Marra, Hubbell).

Another input-reducing transgenic technology involves a gene that confers resistance to glyphosate herbicides. Monsanto used this gene to develop glyphosate-resistant varieties of cotton, soybeans, and corn, which are sold under the brand name Roundup Ready™. One application of Roundup™ herbicide is usually sufficient to achieve effective control of broadleaf weeds. Data from

The worm has turned. GMO traits can target specific pests that are difficult to control.

Photo courtesy of the authors.

the United States suggest that Roundup Ready soybeans increase farmers' profits by an average of $5.65 per acre (Carlson, Marra, Hubbell).

Unlike the first-generation transgenic crops that were designed to lower production costs, second-generation transgenics will feature enhanced nutritional qualities. Plant breeders have tried for decades to develop crop varieties with added vitamins and minerals. Recent advances in genetic engineering methods should allow rapid progress in this area. Nutritionally fortified crops should prove especially valuable in developing countries, where millions of people suffer from chronic dietary deficiencies. They should also be attractive in industrialized countries as a means of reducing consumption of unhealthy oils, proteins, and starches.

7. What are the potential risks associated with GMOs?

Human and animal health

No evidence shows that genetically modified foods are injurious to humans. Even so, there are lingering fears that consuming GMOs might lead to an increase in diseases that are resistant to several antibiotics. This concern developed when some genetically modified crops were found to contain antibiotic resistance genes left over as residue from the bioengineering process. Even though the antibiotic resistance genes are not active, health specialists worried that, if present in sufficiently large numbers, they could accumulate in the bodies of consumers. This concern has recently been allayed, as researchers have devised gene-transfer techniques that avoid the use of the antibiotic resistance genes.

As with any new product, it is important that the potential risks be evaluated before any GMO is approved for commercial use.

Another potential risk posed by GMOs is that people with allergies could suffer reactions after unwittingly consuming modified food containing allergenic substances introduced from external sources. Proponents of GMOs argue that since very few genes produce harmful compounds, the likelihood of this happening is extremely low. And even if an inserted gene were to result in production of a harmful compound, the chances of it reaching consumers are negligible, because it would be found by food safety inspection and testing.

GMOs are also feared by some livestock producers who worry that until the use of antibiotic resistance genes is completely discontinued, animals fed on genetically modified grain could experience a buildup of antibiotic resistance. To date, no evidence has emerged to show that consumption of genetically modified feeds has affected animal health, although few long-term feeding trials have been carried out.

Environmental impacts

Probably the most controversial set of issues surrounding GMOs relates to their possible long-term impacts on the environment. Any crop (transgenic or not) that has been bred to resist pests or diseases carries the risk that the targeted pests or diseases may themselves develop resistance to the crop's defense mechanisms. Some scientists believe that insect resistance to *Bt*-produced toxins will emerge fairly quickly, since insects will be continuously exposed. The recent discovery that several insect species have developed resistance to *Bt* (as a result of exposure to *Bt* sprays, not to transgenic *Bt* crops) has raised renewed questions about the longevity of the resistance.

Another risk linked to the potential emergence of resistance in insects is that *Bt* might lose its effectiveness as a topical pesticide. *Bt*-based sprays and powders are used to control pests in a number of fruit and vegetable crops. Since *Bt* occurs naturally, these pesticides are especially popular among organic farmers. If the widespread planting of transgenic *Bt* crops fosters the emergence of *Bt*-resistant insects, farmers who currently rely on *Bt*-based topical pesticides could suffer important losses.

While some worry that genetically engineered *Bt* crops may not be effective enough, others worry that they will be too effective by killing insects other than the targeted pests. The highly publicized Cornell University monarch butterfly study, which showed a heightened mortality rate among monarch larvae fed on transgenic *Bt* corn pollen, raised the possibility that non-pest insects could be harmed (Losey, Rayor, Carter). After the Cornell study was published, researchers at Iowa State University cautioned against extrapolating from findings obtained under laboratory conditions to the actual conditions faced by wild monarchs (Rice).

Environmental concerns have also been raised about transgenic herbicide resistance. Herbicide-resistant genes could conceivably jump from genetically modified crops to other wild or domesticated species, producing "super weeds" that resist conventional control methods. In order to control these super weeds, farmers might have to switch to more powerful herbicides. Studies are underway to evaluate the potential environmental consequences that might ensue should herbicide-resistant genes accidentally spread from domesticated crops.

8. Why do consumer attitudes about GMOs differ so much around the world?

Consumers have diverse attitudes about GMOs — especially genetically modified food. The Atlantic Ocean apparently represents a major fault line in public sentiment: GMOs seem to have been tacitly accepted in the

Food for thought. In developing countries — where millions go to bed hungry and where food prices directly affect a large proportion of the the population — GMO potential to feed and pay many people cannot be ignored.

Photo courtesy of the authors.

United States, whereas they have inspired widespread protest in Europe. The differences in attitudes appear to be due to two main factors.

First, public awareness of the prevalence of genetically modified food varies greatly. European retailers are required to label products containing GMOs. This requirement has helped alert consumers to the proliferation of genetically modified food. American retailers do not face this requirement and have fought hard to prevent labeling. As a result, most American consumers are not aware that many of the products they consume contain genetically modified ingredients. This lack of awareness has unquestionably contributed to the relative complacency of American consumers.

In places where there is not enough food to go around and where food prices directly affect the incomes of a large proportion of the population, the potential productivity gains offered by GMOs cannot easily be ignored.

Second, consumers on either side of the Atlantic differ in their trust of food safety regulation systems. Americans in general have faith in the government's ability to protect them from unsafe foods, but European regulatory agencies are viewed with suspicion (Gaskell, Bauer, Durant, Allum). The skepticism in Europe stems from recent incidents in which regulatory agencies initially failed to detect the seriousness of food safety problems and then tried to downplay their likely consequences.

9. Are GMOs appropriate for developing countries?

Although the debate over GMOs is taking place mainly in the United States and Europe, developing countries have an important stake in the outcome (Nuffield Council on Bioethics). Many developing countries still depend heavily on agriculture and stand to benefit disproportionately from any technology that can increase food production, lower food prices, and improve food quality. Prince Charles may be correct when he says that GMOs are unnecessary in Britain, where the cost of raw commodities makes up a small fraction of the final price paid by consumers for heavily processed, elaborately packaged, and extensively advertised food. It is hard to make the same argument in developing countries where millions go to bed hungry because food is unavailable or unaffordable. In places where there is not enough food to go around and where food prices

"We would like to be genetically modified to taste like Brussels sprouts."

Everything but the "moo." Consumer-oriented messages use the "genetically modified" terminology but often skirt around the real debate over biotechnolgy.

directly affect the incomes of a large proportion of the population, the potential productivity gains offered by GMOs cannot easily be ignored.

10. What are the long-term prospects for GMOs?

Despite the current uncertainty over the future of GMOs, several things are clear.

First, genetic engineering is too important to ignore. Given recent advances in biotechnology, the process by which humans breed better crop varieties has changed forever. Although it may not always be possible to identify genes of interest and move them around at will, in cases where economically valuable genes can be identified and manipulated, using conventional breeding methods may be inefficient.

Second, the possibility of making gene transfers between and among completely different species of plants, animals, and bacteria opens the door to creating organisms that differ from those that occur naturally. Whether the differences are differences in kind or merely in degree does not really matter. As with any new product, the impacts of GMOs on people, animals, and the environment are difficult to predict, so it is important that the potential risks be evaluated before any GMO is approved for commercial use.

Third, given the importance of food, policies regarding GMOs must be based on an open and honest public debate. In hindsight, it is clear that the agri-biotech industry miscalculated by arguing that genetically modified foods are no different from other foods. This attitude served to heighten suspicions that the industry is seeking to increase profits by promoting a technology that has few benefits and may pose some dangers. In order to move forward, all parties in the debate will have to recognize the validity of others' concerns and take steps to resolve unanswered questions.

Finally, decisions about the future of GMOs should be based on facts, not unsubstantiated claims or half-truths. Many of those engaged in the debate over GMOs use information selectively, glossing over gaps in the knowledge base or bolstering their arguments with misinformation. If the concerns that have been raised are to be resolved, politically motivated rhetoric must give way to serious discussion based on credible, science-based information. The stakes are too high to waste more time on useless posturing. ■

A more comprehensive version of this article can be found at the CIMMYT website. Point your Internet browser to http://www.cimmyt.cgiar.org *then link to "Research Programs," then to "Applied Biotechnology Center."*

■ For More Information

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