

Genetically Modified Crops

Information for New Jersey Farmers

Over the last few years, the issue of genetically modified organisms, or GMOs has become a polarizing one of outsized proportions. This is in large part because of fear and distrust on the part of consumers of a technology that by its nature is highly complex and difficult to understand or explain succinctly, and in part because of the ire raised among much of the public about how genetically modified (GM) crops have been sold and their patents enforced. There has also been considerable effort on the part of many GMO opponents to bring the technology itself into disrepute.

Genetic modification of crops through deliberate selection and propagation of individual plants with desirable qualities is what led to the development of agriculture: a plant that had a larger or sweeter berry was chosen for further propagation. More recently, genetic crosses between plants of a single species or between plants of different species, followed by selection and propagation, expanded the scope of possible traits within a crop. Thus, all modern agriculture is based on “genetically modified organisms”. But that is not what the term has come to mean. GMOs are now defined as organisms whose DNA has been altered using the tools of recombinant DNA technology; other genetic modifications are not included in the definition. GM crops may also be referred to as “genetically engineered” (GE) or “transgenic”, or products of “agricultural biotechnology”. The terms “GM” and “GMO” are used in this paper for simplicity, as they are most recognized among the public.

GMO foods can refer to the crop or livestock species itself or processed food made, in whole or in part, with GMO-containing ingredients. This paper will contain only information about GM plants and plant products. The vast majority of field corn, soybeans, sugar beets, and cotton produced today are raised from GM seeds. In the US, virtually all processed foods and the vast majority of feed for livestock production and pet foods contain products from GM crops.

What are GM crops and recombinant DNA technology?

Genes are often called the building blocks of life, and plants, like other organisms, are made up of thousands of genes. Genes move around in nature from one plant to another through natural breeding processes, but they are also occasionally acquired naturally from other organisms – for example from viruses or bacteria that are resident in the plants. GM plants are produced when genes, parts of genes, or DNA that regulates genes have been added or removed by humans using recombinant DNA technology. Through this process, a single specific trait is given to or removed from the plant intentionally and predictably.

There are many different ways of making transgenic, GM plants, and the variety of methods used to make them is increasing and becoming more sophisticated. Historically, recombinant DNA technologies relied mostly on random “events” that inserted DNA in a non-targeted manner somewhere in the plant’s genetic material. Increasingly, targeted insertion and deletion events are possible at specific positions in the DNA of a plant. The availability of complete plant DNA sequences within the last few years has revolutionized this process. As the technology becomes ever more sophisticated, the time it takes to develop and release GM plants that are adapted to specific growing regions using traditional breeding methods is decreasing.

What does the term “GMO” tell us?

The term “GMO” as commonly used refers only to the general method used to introduce new traits into plants, and says nothing about the content of the plant. If a specific gene is introduced into a plant using methods of recombinant DNA technology, the new plant is classified as GM. If the same gene is introduced into the same plant by methods of traditional breeding and selection, the new plant is not classified as GM. This can occur, for example, when a disease resistance gene is introduced into a plant species from a related species either through traditional breeding or through recombinant DNA technology. Thus, the term “GMO” is functionally meaningless from the standpoints of food safety, environmental impact, or other issues that may be of concern to consumers. In order to evaluate possible safety or environmental impact issues associated with GM crops, each must be evaluated individually.

Are GM crops safe to eat?

All of the major comprehensive studies done to date indicate that currently marketed GM crops are as safe to eat as non-GM crops. These include studies by the U.S. National Academy of Sciences, the U.S. Food and Drug Administration, the American Medical Association, and the World Health Organization to name a few. The few individual research studies that have been cited as providing evidence that an approved GMO food is unsafe have been refuted by the larger scientific community as flawed studies. In some cases, these studies are so demonstrably flawed that they have been retracted by the original publishing journals. A useful scientific study on GMO safety will focus on specific plants or genes and will not generalize results as applying to all GMO technology. For example, a study that examines long-term effects of glyphosate, the active ingredient in the herbicide Roundup® is not a study of a GM crop, but is a study of an herbicide that has been on the market since 1973, well before GMO technology was available. Similarly, a study that examines health effects of transgenic corn bearing the glyphosate resistance gene is not the same as a study examining health effects of glyphosate itself.

GM crops are evaluated individually using state-of-the-art methods to determine whether allergens or toxins have been introduced. More sophisticated studies on long-term biological and health effects of foods, food additives, and pesticides on an individual and on the offspring

of the individual can potentially provide critical information about what we eat. The more we learn about emerging fields such as epigenetics and microbiome effects on human health, the more we realize how much there is to learn. More complex studies are very expensive, difficult, and often yield ambiguous results, and they are rarely done with any product, GM or otherwise. Thus, safety arguments singling out GM crops based on the absence of these types of longitudinal and multigenerational studies are not really appropriate.

What about corporate ownership of GM crops?

Most GM crops are deployed by large corporations. Many of the reasons for this are obvious: it is expensive to develop, test, and market GM crops, and large corporations are more likely to have the capacity to do all of these than small companies or universities. Many GM specialty crops have been initiated at universities, but few of these have been released because of the expense of developing these crops and penetrating the marketplace. One exception has been the development and successful marketing of University of Hawaii's transgenic "Rainbow" papaya that is resistant to a virus that was devastating the Hawaiian papaya crop. Interestingly, this is an example of a transgenic plant whose disease resistance comes from one of the virus's own genes that is present in naturally infected papaya plants. Thus, opponents of this technology have had difficulty raising reasonable safety or environmental arguments as to why "pathogen-derived" resistance such as this would be unsafe or harmful. Nevertheless, GM papayas were fought by the public in the Puna region of Hawaii and the County Council eventually passed a bill that was signed into law preventing biotech companies from operating on the island of Hawaii and banning GM crops. As a compromise, GM papayas were exempted from the law.

Many who are opposed to GM crops are opposed because of their opposition to corporate ownership and enforcement of patents on food crops. While often linked to the GMO issue, this is really a separate issue: traditionally bred crops such as apples, peaches, cranberries, asparagus, dogwoods, strawberries, and many others may be patented and the owners of those patents benefit every time a plant or a fruit is sold. Most all land-grant universities protect their intellectual property by patenting traditionally bred crops and enforcing those patents, although there are some scientists in the plant breeding community who believe that such plants should be distributed freely for direct use and for use in other breeding programs. The aggressive patent enforcement by large corporations on major crops that have been planted extensively, coupled with the relative ease of rapid field identification by owners of their patented material, has brought a great deal of negative publicity to these corporations and associated public backlash.

Does GMO technology reduce the genetic diversity of crop species?

Associated with the issue of ownership of technology is the issue of reduction of the genetic diversity, or "gene pool", of a crop species by focusing on only a single genotype. This is a serious issue, but again it is one that is not limited to the discussion of GMO technology itself. Whether by traditional breeding or by recombinant DNA methods, loss of genes that are part of

a plant's ability to succeed in natural settings occurs when a selection program focuses only on the agronomic qualities of a crop that make the end product most marketable. There are many examples of pests and diseases throughout history that have wiped out crops that have lost such natural resistance through agronomic selection.

When a breeding and selection program assumes the availability of pesticides for use in fending off insect pests and diseases that attack, disfigure, and cause yield reduction in a plant variety, natural resistance genes may be lost from breeding lines. Modern plant breeders are well aware of this problem, and they keep sources of genetic diversity available for possible re-introduction of such genes. In many cases, this involves tracing a plant's heritage back to its region of origin to regain, as much as possible, the gene pool that naturally evolved with a plant species. The process of adding a gene or trait to a plant transgenically relies on starting with a plant line that has been bred for other traits such as yield and quality but also for greatest fitness in a localized region. So, for example, the same single gene may be added using GM technology to hundreds of soybean varieties, each of which has been bred for specific traits and regions.

How common are genetically modified crops in the marketplace?

Food ingredients made with GM crops are ubiquitous in the U.S. marketplace. It is widely acknowledged that approximately 70% of processed foods contain GMO ingredients; thus, it is very difficult to eat commercially available foods without eating GMO products. Globally, nearly 80% of soy, 24% of canola, 32% of corn, and 95% of sugar from sugar beets (50% of total sugar) is from GM plants; the numbers for canola and corn are much higher in the U.S. Most of these crops are herbicide (glyphosate) tolerant and/or insecticide (Bt) expressing. Very few fresh fruits and vegetables use GMO technologies. Notable exceptions include sweet corn, papaya and squash.

While currently available GMO foods are limited in terms of crop species and technology deployed, the potential of transgenic plant technology is great. Examples of developed or developing technologies include "Golden Rice" that contains the vitamin A precursor β -carotene and could be an invaluable adjunct in preventing blindness and death worldwide, and a rice-based, edible rotavirus prophylaxis and therapy that could be instrumental in decreasing this predominantly developing world disease. Overall, these technologies are still young and relatively little has been invested in their development in global terms.

Should GMO foods be labeled?

Legislation mandating the labeling of foods containing GMO ingredients is currently under consideration in a number of U.S. states. Very recently, Vermont became the first state to pass stand-alone legislation requiring labeling of GMO foods and have it signed into law. At the same time, efforts at the U.S. federal level to develop regulations defining the federal government and not individual states as the administrator of any such labeling are also underway. This

would parallel the situation with the meat industry in the U.S., which is under federal and not state jurisdiction.

Current labeling of GMO food is done proactively by food producers and distributors for marketing. Organic foods as certified by the USDA are by definition GMO-free – the Certified Organic label alone is sufficient to assert that a food is free of GMO ingredients. Foods that are not certified by USDA as organic may also be GMO-free and be labeled as such, in accordance with policy of the Food and Drug Administration. These labels are effective tools for producers who wish to market to an audience that wants GMO-free food.

A major problem with GMO labeling laws currently under consideration is that the term “GMO” says nothing about content of a given food, but only about a type of technology that was used to develop the food. It is in effect legislating against a process and not an end product. Unlike providing information about specific ingredients, calorie content, or allergens in foods, labeling foods simply as “GMO” is of no value in educating consumers about food content. So, from an educational standpoint, it is insupportable to label foods as “GMO” with no further description – it is a non-informational label. While more descriptive labels specifying the actual content of food could be required (e.g., describing the specific introduced gene), these would likely be of limited value because of the confusion that would likely arise among customers. But they are more supportable from a scientific and informational perspective than proposed laws that provide no such information. Legislation currently under consideration in New Jersey, and similar legislation under consideration in several other states, would only require a label stating that a food is “GMO”.

What about Bt sweet corn?

Sweet corn that has been genetically engineered to express *Bacillus thuringiensis* insecticidal crystal (Cry) proteins is one of only three genetically engineered fruit and vegetable crops commercially available. Coming from a naturally occurring bacterium, the Bt Cry proteins themselves are approved for certified organic labeling when sprayed onto the corn, but not when deployed transgenically. Among scientists who are concerned about pesticide use, Bt sweet corn is a success story: it has reduced the use of insecticides such as pyrethroids and carbaryls.

Proponents of Bt sweet corn point to the dramatic reduction in pesticide use and attendant decrease in non-target, potentially beneficial insect killing provided by the technology. Opponents argue that more of the Bt toxin is ingested in transgenic corn than in Bt-treated, non-transgenic corn, and that the Cry protein genes can potentially escape into wild plants. The same arguments against corporate control of GM crops noted above apply to Bt sweet corn.

How does the public perceive GMO foods?

From the marketers standpoint, the most important thing is whether or not customers will buy foods, especially fresh market vegetables, that they know were made with transgenic

technology. The recent study from Rutgers professor Dr. William Hallman and his colleagues suggests that public awareness and knowledge of GMO foods is relatively low, but that public opinion about GMO foods is generally negative. As a result, nearly 75% believe that labeling of GMO foods should be required. Unfortunately, studies examining how consumers receive and process scientific information about the safety of GMO foods are not encouraging. The U.S. Farmers and Ranchers Alliance now suggests that celebrities rather than experts must be engaged to deliver the message of GMO food safety.

If you grow or sell GM crops, what can you tell your customers?

- If customers ask whether you are selling GMO foods and you are, tell the truth about it.
- Unless you are very well-read and understand the breadth of research on the GM crops and foods, don't try to get into a deep conversation about the issue with customers. You are unlikely to change the opinion of someone with strong views.
- Reasons you choose to grow GM sweet corn might include:
 - It is a safe technology that relies on the same naturally occurring Bt toxin that is approved for organic use.
 - It has allowed you to reduce pesticide inputs, reducing risk to non-target insects, including natural enemies of other crop pests.
 - At an affordable price, you are delivering safe, fresh, locally grown corn that is free of corn earworms.

For the complex issue of GM crops and foods, scientists will continue to provide their best research and information, as they do for other contentious subjects such as climate change and evolutionary biology; celebrities and non-experts will weigh in with disproportionately loud voices on the issue, industry leaders will drive their corporate processes, and policy makers will help decide what they think is in the public's best interests. In the end, the local and global marketplace will decide the fate of GMO technology.

Below are some resources for further reading:

Bittman, M. 2014. Leave 'Organic' out of it. NY Times, May 6, 2014.

http://www.nytimes.com/2014/05/07/opinion/bittman-leave-organic-out-of-it.html?_r=0

DeFrancesco, L. 2013 US Congress moves to 'protect' GM crop plantings. Nature Biotechnology 31, 479.

<http://www.readcube.com/articles/10.1038/nbt0613-479>

Hallman, W.K., Cuite, C.L., and Morin, X.K. 2013. Public perceptions of labeling genetically modified foods. Working Paper 2013-01.

http://humeco.rutgers.edu/documents_pdf/news/GMlabelingperceptions.pdf

Harmon, A. 2013. A Race to Save the Orange by Altering Its DNA. NY Times, July 27, 2013.

<http://www.nytimes.com/2013/07/28/science/a-race-to-save-the-orange-by-altering-its-dna.html?pagewanted%3Dall>

Harmon, A. 2014. A lonely quest for facts on genetically modified crops. NY Times, Jan. 4, 2014.
<http://www.nytimes.com/2014/01/05/us/on-hawaii-a-lonely-quest-for-facts-about-gmos.html>

Jacobs, H. 2014 Poison running through my veins. EMBO Reports 15: 123.
<http://embor.embopress.org/content/early/2014/01/09/embr.201338286>

Jaffe, G. 2012. Straight Talk on Genetically Engineered Foods: Answers to Frequently Asked Questions. Center for Science in the Public Interest.
<http://cspinet.org/new/pdf/biotech-faq.pdf>

Jaffe, G. 2013. What you need to know about genetically engineered food. The Atlantic, February 2013.
<http://www.theatlantic.com/health/archive/2013/02/what-you-need-to-know-about-genetically-engineered-food/272931>

James, C. 2013. ISAAA Brief 46-2013. International Service for the Acquisition of Agri-Biotech Applications.
<http://www.isaaa.org/resources/publications/briefs/46/executivesummary/default.asp>

National Academies Press 2004. Safety of genetically engineered foods: Approaches to assessing unintended health effects. National Academies Press, 2004.
http://www.nap.edu/openbook.php?record_id=10977&page=7

Shelton, A.M. 2013 Bt Sweet Corn: A Commercial Product for the Public Good. ISB News Report, December 2013.
<http://www.isb.vt.edu/news/2013/Dec/Shelton.pdf>

Some contacts at Rutgers University for information about GMO crops and technology:

Cuite, Cara (cuite@aesop.rutgers.edu) GMO policy and perception
Di, Rong (di@aesop.rutgers.edu) Molecular biology of GM plants
Goodman, Robert (execdean@aesop.rutgers.edu) General information about GM crops
Hallman, William (hallman@aesop.rutgers.edu) GMO policy and perception
Hillman, Bradley (hillman@aesop.rutgers.edu) General information about GM crops
Hlubik, William (hlubik@aesop.rutgers.edu) Public communications about GM crops
Leustek, Thomas (leustek@aesop.rutgers.edu) Molecular biology of GM plants
Morin, Xenia (morin@aesop.rutgers.edu) General information about GM crops
Pray, Carl (pray@aesop.rutgers.edu) – International economics of GMO crops
Rabin, Jack (rabin@aesop.rutgers.edu) - Public communications about GMO crops
Zilinskas, Barbara (zilinskas@aesop.rutgers.edu) - Molecular biology of GM plants

Selected web resources:

The internet is awash with misinformation about GMOs and GM crops, but there are many excellent resources as well. Below are a few sites that I find particularly useful:

International Service for the Acquisition of Agri-Biotech Applications
(<http://www.isaaa.org/gmapprovaldatabase/default.asp>)

Center for Science in the Public Interest (<https://www.cspinet.org>)

University of California Division of Agriculture and Natural Resources Statewide Biotechnology Workgroup (<http://ucbiotech.org/>)

Note: This short summary is meant to be informational, and not meant to be a referenced paper. It was written by Dr. Brad Hillman, Department of Plant Biology and Pathology and Director for Research, New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, NJ 08901-8525; hillman@aesop.rutgers.edu, who is responsible for content. Thanks to Greg Jaffe for useful editorial comments.