Environmental and Health Risks of GMOs
James Riddle, Director, Organic Independents LLP
3rd International Conference on Trade and Market Development of Organic Products – August 25, 2015 – Tehran, Iran

Introduction

Genetically modified organisms, or GMOs, have historically been prohibited for use in organic production and processing. When the United States Department of Agriculture (USDA) proposed in 1997 that GMOs be allowed in organic production, a record-setting 275,000 commenters said, "No GMOs in Organic." Eventually, the use of GMOs was prohibited in the National Organic Program Final Regulation, with GMOs being defined as "excluded methods."[1]

Beyond my work to help establish US organic regulations, I became involved in the GMO issue in 2002, when our 16-year old daughter and two friends did a Science Fair project examining the effects of transgenic Bt field corn on earthworms.

My daughter and her friends grew Bt and non-Bt corn in plastic 5-gallon buckets. Before the plants shed pollen, the girls pulled up the plants, dried them, then ground up the plants, including the roots. They tested the plant residues to establish the presence (and absence) of the Bt toxin. The plant residues were mixed with earthworm bedding and placed in insulated, replicated chambers with 5 earthworms per chamber, under cool, dark conditions. The earthworms were removed and examined weekly.

The earthworms in the chambers with Bt corn residues consistently developed lesions, lost weight, and died. The earthworms in the non-Bt corn gained weight and were healthy. The girls won 2nd prize at the 2002 International Science Fair.

There is something wrong with transgenic technology and the regulatory system, if high school girls can show damage to soil organisms that should have been exposed in the regulatory process, so I began to take a deeper look into the environmental and health impacts of GMOs and how they are regulated.

What are GMOs?

Genetically Modified Organisms, or GMOs, are organisms that have been created by transferring genetic material from one species, family or kingdom to another, in ways that could never be achieved through natural breeding or reproduction. GMOs are novel, patented, transgenic plants, animals and micro-organisms that have never before existed in nature or been part of the human diet.

How Are GMOs Regulated in the United States?

GMOs are regulated in the U.S under the "Substantial Equivalence" doctrine. Substantial equivalence means that if a GMO crop contains comparable amounts of a few basic components, such as proteins, fats, and carbohydrates, as its non-GMO counterpart, then the GMO crop is substantially equivalent to the non-GMO. Under this paradigm, GMOs and non-GMOs are the same; therefore, no compulsory safety

testing is required by the regulatory agencies, and there is no need to label foods containing GMOs. Even though GMOs are made in a lab using genetic engineering techniques and are patented because they are unique, substantial equivalence states that they are considered to be equal to traditional crops.

The substantial equivalence policy was announced by then-Vice President Dan Quayle in 1992. In order to facilitate the commercialization of GMOs, it was determined that no new regulations were needed to oversee this emerging technology. Instead, a "coordinated framework" was established.

Under the coordinated framework, the US Food and Drug Administration (FDA) treats transferred genetic material and foods derived from GM crops as food additives, subject to existing food additive regulation, under which the transgenic material may be considered "generally recognized as safe" GRAS) or not, at the *producer's determination*. If the GMO crop produces an insecticide, as is the case with Bt corn and cotton, then the crop is registered as a pesticide with the Environmental Protection Agency. If the plant has the possibility of being a plant pest, then it is de-regulated by the USDA's Animal Plant Health Inspection Service (APHIS) prior to being sold and planted.

Regardless of which agency has responsibility, the regulatory system relies on voluntary consultations with biotech companies, whereby the companies notify the agency of their intent to commercialize a product. They submit their own test results. The agencies review the company's studies and "de-regulate" the transgenic product. The agencies do not conduct their own scientific studies on the health or environmental impact of the novel products being de-regulated.

The only system of agriculture in the U.S. that prohibits the use of GMOs is organic, which is regulated by the USDA National Organic Program. The only government-regulated food label, which means that no GMOs have been used is the "organic" label. Even so, the USDA has made it clear that GMOs might be found in organic foods, due to "adventitious presence" (cross pollination or contamination). There is no regulatory rejection level for GMO contamination of organic foods in the U.S., but buyers of sensitive crops commonly test for the presence of GMOs.

Who Owns GMOs?

The bulk of GMOs are owned by Monsanto, Bayer Crop Science, Syngenta, Dow, DuPont, and BASF. Farmers who plant GMO crops do not own the seed. They sign licensing agreements, (which also prevent the crop from being used for research), to plant the patent-holders' technology. Farmers have been sued for saving seeds.

What GMOs are on the Market and in the Food Supply?

The first GMO food product to be approved in the U.S. was milk from cows treated with recombinant bovine somatotropin, which is a genetically engineered artificial hormone injected into dairy cows to make them produce more milk.

Over 90% of the field corn grown in the U.S. is genetically engineered to withstand herbicide applications; contain Bt toxins to kill corn borer and/or corn rootworms; or to contain an enzyme, amylase, to break down starches into sugars

for the production of ethanol. Many GM corn varieties have "stacked traits," such as herbicide tolerance and insecticidal proteins, in the same seed.

Most of the soybeans grown in the U.S. have been engineered to tolerate the herbicide glyphosate (Roundup Ready®), as has much of the canola and sugar beets. In recent years, Roundup Ready® alfalfa has been released, as has Bt sweet corn. Much of the cotton grown in the U.S. contains the Bt trait. Disease resistant Hawaiian papayas and zucchini yellow summer squash are also being grown.

Due to the rapid increase in glyphosate-resistant weeds, corn and soybeans engineered to withstand 2,4-D (Agent Orange) and Dicamba herbicides have been recently released. Herbicide tolerant wheat has been developed, but has not yet been released due to resistance from flour milling and export industries. GM potatoes and non-browning apples have been released, and transgenic, fast-growing salmon and trees are soon to be on the market.

What is Science Revealing about GMOs?

Independent research on GMOs has revealed some disturbing trends, including:

Horizontal Gene Transfer
Cauliflower mosaic virus (CaMVP-35S) is used to insert foreign genes into host transgenic organisms. Research has revealed that: 1) Ingested fragments from the CaMVP-35S promoter are incorporated into blood, liver, and brain tissues of experimental rats; and 2) The total amount of GM sequences transferred to the rats increased significantly by increasing the feeding duration.[2]

Formadehyde in GM Soy
MIT-trained systems biologist Dr. V.A. Shiva Ayyadurai published a study in 2015 finding that genetically engineered soy contains more formaldehyde, a class 1 carcinogen, and markedly less glutathione, an anti-oxidant necessary for cellular detoxification, than non-GM soy.[3]

Glyphosate Residues in GM Soy
GM soy from the state of Iowa contained high residues of glyphosate and AMPA, a breakdown product of glyphosate. Conventional and organic soybeans contained none of these agrochemicals. Organic soybeans showed the healthiest nutritional profile with more sugars, such as glucose, fructose, sucrose and maltose, significantly more total protein, zinc and less fiber than both conventional and GM-soy. Organic soybeans also contained less total saturated fat and total omega-6 fatty acids than both conventional and GM-soy.[4]

GM Bt Toxin Found in Midwest Streams
According to researchers from Notre Dame, Loyola, Indiana and Southern Illinois Universities, Bt corn residues and associated Cry1Ab proteins are widely distributed and persistent in the headwater streams of the U.S. Corn Belt landscape, and can be measured in water bodies 6 months after harvest.[5]

Bt Corn Harms Aquatic Organisms
Researchers at Indiana University have found that genetically engineered Bt corn harms aquatic insects and disrupts stream ecosystems. Caddisfly (*Trichoptera)* larva experienced high mortality and stunted growth when exposed to Bt corn pollen and crop residues.[6]

Bt Protein Harms Ladybird Beetles
Researchers from the Swiss Federal Institute of Technology (ETH) in Zürich confirm earlier findings that the Bacillus thuringiensis (Bt) toxin Cry1Ab produced for pesticidal purposes by genetically modified (GM) Bt maize increases mortality in the young ladybird larvae (*Adalia bipunctata* L., two-spotted ladybird).[7]

Monarch Butterfly Declines Linked to Planting GM Crops
Published University of Minnesota research attributes decreasing Monarch butterfly populations to the loss of milkweed from the widespread use of "Roundup Ready®" crops on millions of acres in the U.S.[8]

Emergence of Bt-resistant Corn Rootworms
Corn rootworm (*Diabrotica virgifera)* resistance to Bt corn hybrids expressing the Cry3Bb1 toxin has been documented by University of Minnesota and Iowa State University researchers.[9]

Neonicotinoid Insecticides Found in Streams
Partly due to the emergence of Bt-resistant corn rootworms, there has been a dramatic increase in the use of neonicotinoid seed treatments for corn and soybeans. An area of intense corn and soybean production in the Midwestern U.S. was chosen by the U.S. Geological Survey to study because of the high agricultural use of neonicotinoids via both seed treatments and other forms of application. Water samples were collected from nine stream sites during the 2013 growing season. Neonicotinoids were detected at all nine sites sampled. Temporal patterns in concentrations reveal pulses of neonicotinoids associated with rainfall events during planting, suggesting seed treatments as the likely source. Concentrations frequently exceeded chronic aquatic toxicity values during the growing season.[10]

GM Canola Escapes
Scientists in North Dakota have found that genetically engineered canola has escaped and cross-pollinated with wild relatives, creating transgenic weeds that are resistant to herbicides.[11]

Glyphosate-resistant Weeds
Over 20 glyphosate-resistant weed species have been identified in the United States, with glyphosate-resistant horseweed, waterhemp and giant ragweed found throughout Illinois and Iowa. Weed scientists recommend applications of Atrazine, Simazine, 2,4-D, and other herbicides, in addition to glyphosate, for control.[12]

GM Crops Increase Herbicide Use

Based on analysis of USDA pesticide use data, herbicide-resistant crop technology has led to a 527 million pound increase in herbicide use in the United States between 1996 and 2011, directly related to the planting of GM crops.[13]

GM Soy, Birth Defects and Child Cancer

Argentinean physicians have reported significant increases in birth defects, miscarriages and child cancer in towns surrounded by GMO soy fields sprayed with glyphosate. In Chaco Province, the rate of birth defects increased from 19.1 per 10,000 in 1997 to 85.3 per 10,000 in 2008. Cases of child cancer rose from 29 to 40 per year from 1985 to 2001.[14] [15]

Roundup-Ready® Corn - 2-year Rat Feeding Trials

The health effects of Roundup-Ready® corn (from 11% in the diet), cultivated with or without Roundup®, and Roundup® alone were studied for 2 years in rats. In females, all treated groups died 2–3 times more than controls, and more rapidly. In treated males, liver congestions and necrosis were 2.5–5.5 times higher. Marked and severe kidney nephropathies were also generally 1.3–2.3 greater. Males presented 4 times more large palpable tumors than controls, which occurred up to 600 days earlier. Biochemistry data confirmed very significant kidney chronic deficiencies for all treatments and both sexes.[16]

Bt Toxin Found in Maternal Blood

Cry1Ab, a specific type of Bt toxin from genetically modified (GM) crops, has been detected in human and fetal blood samples. Upon testing 69 pregnant and non-pregnant women who were eating a typical Canadian diet (which included GM corn and soy) researchers found the Bt toxin in:

- 93 percent of maternal blood samples
- 80 percent of fetal blood samples
- 69 percent of non-pregnant women blood samples[17]

Bt Protein Toxic to Human Cells

Bt toxins, such as those produced in genetically engineered plants, can be detrimental to human cells. This is a conclusion of research led by researchers at the University of Caen (France). "Modified *Bt* toxins are not inert on nontarget human cells, and they can present combined side-effects with other residues of pesticides specific to GM plants."[18]

GM Feed Effects on Hogs

Hogs in Iowa were fed either a mixed GM soy and GM corn diet or an equivalent non-GM diet in a long-term toxicology study of 22.7 weeks, the normal time from weaning to slaughter. GM-fed female pigs had uteri that were 25% heavier than non-GM fed pigs, a condition which can cause reproductive problems for sows. GM-fed pigs had a higher rate of severe stomach inflammation with a rate of 32% of GM-fed pigs compared to 12% of non-GM-fed pigs. The severe stomach inflammation was worse in GM-fed males compared to non-GM fed males by a factor of 4.[19]

Glyphosate and Beneficial Gut Bacteria In Poultry
A 2012 study published in *Current Microbiology* showed that glyphosate, the main ingredient in Roundup®, is toxic to beneficial gut bacteria in poultry. Disease-causing bacteria, such as *Salmonella* and *Clostridium*, are resistant to glyphosate.[20]

Study Links Glyphosate, 2,4-D and Dicamba to Antibiotic Resistance
Exposures of *E. coli* and *Salmonella t*o commercial formulations of three herbicides were found to induce a changed response to antibiotics. "Increasingly common chemicals used in agriculture, domestic gardens, and public places can induce a multiple-antibiotic resistance phenotype in potential pathogens. The magnitude of the induced response may undermine antibiotic therapy and substantially increase the probability of spontaneous mutation to higher levels of resistance."[21]

World Health Organization Names Glyphosate "Probable Carcinogen"
Researchers from the International Agency for Research on Cancer, (the cancer research arm of the World Health Organization), found there was "limited evidence" in humans that glyphosate can cause non-Hodgkins lymphoma and convincing evidence that glyphosate can also cause other forms of cancer in rats and mice.[22]

Increase in U.S. Childhood Food Allergies
According to a study released in 2013 by the U.S. Centers for Disease Control and Prevention, food allergies among American children increased approximately 50% between 1997 and 2011.[23]

AAEM Position on Genetic Engineering
The American Academy of Environmental Medicine has concluded that "GM foods pose a serious health risk in the areas of toxicology, allergy and immune function, reproductive health, and metabolic, physiologic and genetic health."[24]

Why the U.S. Should Label Foods Containing GMOs

- No pre-market human health safety testing is required.
- Labeling provides the ability to conduct epidemiological studies.
- Labeling helps identify environmental and public health impacts.
- Labels helps establish food justice and end food system monopoly.
- Labels allows people to exercise their freedom of religion.
- Labeling will help provide market opportunities for non-GMO farms.
- 64 countries, including the United States' major trade partners, already require labeling.
- Labeling will help bring transparency, accountability, and honesty to the food system.
- Labels on GMO foods will let the free market decide the fate of this novel technology.
- Labels will allow consumers to make informed food purchasing decisions.

[1] *7 CFR part 205 National Organic Program Final Regulation*, 205.2 Terms Defined, *Excluded methods.* "A variety of methods used to genetically modify organisms or influence their growth and development by means that are not possible under natural conditions or processes and are not considered compatible with organic production. Such methods include cell fusion, microencapsulation and macroencapsulation, and recombinant DNA technology (including gene deletion, gene doubling, introducing a foreign gene, and changing the positions of genes when achieved by recombinant DNA technology). Such methods do not include the use of traditional breeding, conjugation, fermentation, hybridization, in vitro fertilization, or tissue culture."

[2] *African Journal of Biotechnology*, Vol.13(48), pp. 4410-4418 , November 2014.

[3] *Agricultural Sciences*, July 2015.

[4] *Food Chemistry* 153 (2014) 207–215.

[5] *Proceedings of the National Academy of Science*, 2010."Occurrence of maize detritus and a transgenic insecticidal protein (Cry1Ab) within the stream network of an agricultural landscape" *http://www.pnas.org/content/early/2010/09/22/1006925107.full.pdf*

[6] *Proceedings of the National Academies of Sciences.* (Vol. 104, No. 41).

[7] *Environmental Sciences Europe* 2012, 24:10 doi:10.1186/2190-4715-24-10 www.enveurope.com *http://www.sciencedaily.com/releases/2012/02/120227111158.htm*

[8] *Insect Conservation and Diversity,* 2011. "Decline of monarch butterflies overwintering in Mexico: is the migratory phenomenon at risk?" *http://onlinelibrary.wiley.com/doi/10.1111/j.1752-4598.2011.00142.x/abstract*

[9] *PLoS One,* 2011. "Field-Evolved Resistance to Bt Maize by Western Corn Rootworm." Gassmann AJ, Petzold-Maxwell JL, Keweshan RS, Dunbar MW. *http://www.plosone.org/article/info:doi%2F10.1371%2Fjournal.pone.0022629*

[10] *Environmental Pollution*, Volume 193, October 2014, Pages 189–196.

[11] *PLoS One.* 2011;6(10):e25736. Epub 2011 Oct 5. *http://www.plosone.org/article/info:doi/10.1371/journal.pone.0025736*

[12] *Weed Science,* Oct-Dec 2011. *http://web.extension.illinois.edu/ajmpu/news/news26408.html*

[13] *Environmental Sciences Europe,* September 28, 2012. http://www.enveurope.com/content/24/1/24/abstract

[14] *http://www.reduas.fcm.unc.edu.ar/wp-content/uploads/downloads/2011/10/INGLES-Report-from-the-1st-National-Meeting-Of-Physicians-In-The-Crop-Sprayed-Towns.pdf*

[15] *GM Watch,* April 2015. "The case for banning Roundup®" Dr Jeff Ritterman. http://www.gmwatch.org/index.php/news/archive/2015-articles/16093-argentina-cancer-increased-fivefold-in-town-near-gm-soy-and-maize-fields-study

[16] *Environmental Sciences Europe Journal.* 2014.

[17] *Reproductive Toxicology*, Volume 31, Issue 4, May 2011, Pages 528-533. "Maternal and fetal exposure to pesticides associated to genetically modified foods in Eastern Townships of Quebec, Canada."

[18] *Journal of Applied Toxicology.* Feb 15, 2012. *"Cytotoxicity on human cells of Cry1Ab and Cry1Ac Bt insecticidal toxins alone or with a glyphosate-based herbicide."*

[19] *Journal of Organic Systems*, 2013. Vol. 8 No. 1.

[20] *Curr Microbiol.* 2012 Feb 24. Emilie Clair, Laura Linn, Carine Travert, Caroline Amiel, Gilles-Eric Séralini, Jean-Michel Panoff. "Effects of Roundup® and Glyphosate on Three Food Microorganisms: Geotrichum candidum, Lactococcus lactis subsp. cremoris and Lactobacillus delbrueckii subsp. bulgaricus."

[21] *mBio* ,American Society of Microbiology, 2015. http://mbio.asm.org/content/6/2/e00009-15

[22] *The Lancet Oncology*, March 20, 2015. http://www.thelancet.com/journals/lanonc/article/PIIS1470-2045(15)70134-8/fulltext

[23] Centers for Disease Control and Prevention, Food Allergy Research and Education. http://www.foodallergy.org/facts-and-stats

[24] *Executive Committee of the American Academy of Environmental Medicine*, May 8, 2009.