Genetically Modified Organisms Can Be Organic

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Genetically modified organisms (GMOs) or genetically modified technology is currently considered an "excluded method" not allowed to be used in, or added to, organic agricultural products under the US Code of Federal Regulations. Despite evidence that GMOs may serve as a safe alternative to conventional crops, they are frequently associated with harmful and unsustainable agricultural practices. We discuss the economic, environmental, nutritional, and food safety concerns of GMOs in organic agriculture, and how GMO technology could benefit it. We propose (1) allowing the use of genetic modification in organic agriculture and (2) an enhanced effort to disseminate science-based information to consumers. Nutr Today. 2021;56(1):26–32

Tools to improve organic crop operations and yields are needed.[1] The economic, nutritional, and environmental benefits of genetically modified (GM) food may improve organic crop production. For that reason, we propose the removal of GM materials (ie, seeds and plantules [embryos beginning germination]) from the "excluded methods and procedures" for organic certification. In 1986, the US Executive Office of the President and the Office of Science and Technology Policy released the Coordinated Framework for Regulation of Biotechnology to regulate the use of GM, conventional, and organic materials in the United States. As defined in the Code of Federal Regulations (CFR), genetic modification is the "production of heritable improvements in plants or animals for specific uses, via either genetic engineering or other more traditional methods," and a GM organism (GMO) is "an organism produced through these genetic modifications." As opposed to conventional plant breeding practice, a gene from a different species is inserted into the plant cell. For example, *Bt* (*Bacillus thuringiensis*) corn contains genetic material from *Bt*, a bacterium that grows naturally in the soil. *Bacillus thuringiensis* produces crystal-like proteins during spore forming, which, when ingested by a susceptible insect, the crystals act like a poison. The benefit of these proteins is their specificity to some groups on insects, harming only crop pests and leaving beneficial insects alone. Moreover, they have no effects on mammals.[2] Inserting genes from different species is one of the main issues of concern regarding the use of GMOs.

Organic agriculture, on the other hand, is "a concept and practice of agricultural production that focuses on production without the use of synthetic inputs and does not allow the use of transgenic organisms" according to the CFR.[3] To use the US Department of Agriculture (USDA) organic label, farmers must undergo a certification process[4] demonstrating compliance with all the organic standards of the USDA National Organic Program. The CFR outlines the criteria for allowed and prohibited substances, methods of production, and ingredients for organic agriculture. Under the CFR Section 205.2, "excluded methods" are defined as "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. Excluded methods include cell fusion, microencapsulation and macro-encapsulation, 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). However, excluded methods do not include the use of traditional breeding, conjugation, fermentation,

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hybridization, in vitro fertilization, or tissue culture."[3] Under these excluded methods, genetic engineering is prohibited in all organic agriculture including animal feed, seeds, and seedlings.

The American Medical Association, the National Academy of Sciences, the American Association for the Advancement of Science, and the World Health Organization (WHO) are among the health organizations that support the use of GM crops based on the totality of scientific evidence.[5–7] Nevertheless, concerns about safety remain one of the major reasons consumers reject GMO products, and public perception remains mixed regarding the safety of GMO consumption. It seems that consumers agree that produce and products developed with the use of GM technology should be identified in the marketplace,[8] with voluntary labeling, including "non-GMO" or "GMO free." However, these and other targeted keywords such as "natural," "cage-free," "grass-fed," and "sustainable" likely contribute to the negative perception of GM products and produce, driving sales to the organic market.

With a projected 6.5 million acres of organic farmland in 2019, if GMO technology was introduced to organic crops, there is potential to substantially increase crop yield.[9] "The UN projects a population of 9.7 billion in 2050, creating a monumental challenge for feeding the world."[10] Genetically modified technology is a potential solution to food security while simultaneously reducing environmental impact. Simultaneously, there is substantial evidence that agrochemicals widely used in conventional agriculture pose environmental burdens.[11,12] Organic agriculture may assist in establishing an ecological balance by preventing or reducing soil infertility, pest problems, and water pollution; encouraging the use of renewable energies; and promoting biodiversity preservation.[13] However, current organic practices produce lower yields. Genetically modified organism technology could be critical in sustaining organic agriculture as future populations demand more and higher quality food.

Policy change or legislation may be in order that allows the use of GMOs in organic agriculture, eliminating recombinant DNA technology from "excluded methods." The effect of this change to the CFR would require any GM production to follow the same certification methods already specified by the CFR for organic products. Thus, the use of synthetic pesticides, such as glyphosates, would be prohibited. Research-based government-issued education is also needed to inform consumers and producers about the benefits and safety of GM technology, backed by leaders in agriculture and nutrition research. In addition, voluntary labeling, including non-GMO or GMO-free, is perceived as needed by many consumers. However, producers argue that these and other targeted keywords likely contribute to the negative perceptions of GMO products. Some argue that these labels should be restricted.

CONSUMER PERCEPTIONS OF GMO PRODUCTS

Genetically modified foods inspire passionate beliefs among many consumers, but studies show that most consumers do not have the knowledge to support their opinions. Overall, American knowledge of GMO is very low, with 54% of a sample population stating they know very little or nothing at all about GM foods.[14] Without knowledge about the production or safety of GM produce, it is not surprising that consumers are skeptical. Only 45% of Americans from the Hallman et al[14] study believed GM foods were safe to consume. Furthermore, 75% of a sample of American consumers express GMO safety concerns related to health.[8] In a recent European poll, 61% of participants did not support use of GM foods because of the perceived issues of pesticide residues, presence of antibiotics/hormones in meat products, and potential pollutants.[15,16] Yet, when given the choice between purchasing GM versus organic products, shoppers did purchase GM products regardless of perceived issues due to the lower price.

There is also a lack of understanding among consumers about the potential benefits of GM crops. In the Angus Reid Group poll in 2000, only 31% of participants were aware that GM crop technology increased yield. From the same poll, only 15% were aware that GM technology can improve food quality (eg, golden rice) and leads to a reduction in pesticide use. There seems to be an assumed "unnatural" stigma surrounding GM crops, because many think more pesticides and toxins are used in the growing process. This perception drives consumers to the organic market as they believe organic crops are chemical free and uncontaminated.[17] Consumers also value and are willing to pay a premium for products they believe reflect values such altruism, ecology, and universalism with nature.[17] Moreover, organic product consumers are more responsive to farm worker conditions and motivated to support local and small community businesses.[18] We argue that, in contrast, GMO crops are associated with multinationals and other large corporations and generally rejected by consumers. With society making decisions based on assumptions rather than science, there is clearly a need for education about GM foods.

SAFETY AND NUTRITIONAL ADEQUACY OF GMO PRODUCTS

Recent research has increasingly focused on GMO safety. Global leaders in food, nutrition, and food safety unanimously agree that GMOs are safe for human consumption. Since 2006, the number of publications and reviews on the safety of GMOs has dramatically increased.[7] The 2016 report, *Genetically Engineered Crops: Experiences and Prospects*, examined all current literature and reexamined past literature related to GMO safety.[19] There were sufficient experimental studies to conclude that there are no adverse health effects on humans or animals after the consumption of GMOs. The authors found parallel results with long-term studies and studies that examined epidemiological data on cancer outcomes.[20] Furthermore, a 2018 meta-analysis based on 21 years of data demonstrated significantly lower toxins from fungal contamination in GM versus non-GM corn.[20]

Concurrent with GMO safety, evidence indicates nutritional equivalence of GMOs and their nonmodified counterparts, and this view is supported by federal agencies.[19] Venneria et al[21] compared the nutritional content of GMO and non-GMO samples of wheat, tomato, and corn and found no significant differences in fatty acid content, phenols, polyphenols, carotenoids, vitamin C, and mineral composition. The findings are consistent with the WHO, the Organization for Economic Cooperation and Development, and the UN Food and Agriculture Organization's stance on the nutritional equivalency of approved GMO foods in the marketplace.[18,22,23] In addition, GMO foods have been evaluated for allergenicity by the UN Food and Agriculture Organization and the WHO, and no allergenic effects have been found.[23]

Organic crops in developing countries often fail in response to insects, weather, and/or unfavorable farming conditions such as infertile soil. Biotechnology can provide resistance to such conditions and can thus help improve harvests in countries where malnutrition is endemic. For example, the *Bt* gene was introduced to Spanish crops in 1998 to generate a toxin specific to produce-harming insects.[24] The *Bt* gene has been deemed as safe for both human consumption and the environment by the WHO and the Environmental Protection Agency (EPA), respectively. Brookes and Barfoot[25] estimate that 35% (or 29.9 million kg) fewer pesticides were used globally due to *Bt* corn.[26,27]

Controversy still exists around GMO products and their effects on food security. Genetically modified crops can potentially increase food security by increasing household income and, thus, the availability of nutritious food. Brookes and Barfoot[25] estimated a 17.7-billion–dollar global direct income benefit from GM corn, soybean, canola, and cotton crops over 19 years. Qaim and Kouser[28] studied the impact of bioengineered cotton on 1431 local farming households in India and found that adopters of *Bt* cotton increased food security by 15% to 20%. Furthermore, adopters of *Bt* corn significantly increased their daily caloric intake by ~150 kcal/d, with nearly 50 of those calories attributed to nutrient-rich foods such as pulses, fruits, vegetables, and animal products.[28] *Bacillus thuringiensis* cotton is heavily produced in developing countries including China and Pakistan, and studies have suggested that the introduction of *Bt* cotton has significantly increased income, reduced pesticide use, and decreased poverty.[6,29,30]

A union of GMOs and organic foods could be a win-win for consumers.

ORGANIC AGRICULTURE AND GM TECHNOLOGIES: DUAL ADVANTAGES

Organic agriculture aims to preserve natural resources and protect biodiversity. Organic agriculture used in combination with GMO techniques gains the dual advantage of a rapid targeted selection process and maintenance of biodiversity. A recent study from the *Journal of Soil and Water Conservation* correlates water-holding capacity with increased organic matter in soil, a key aim of organic farming methods.[31] Organic food systems also protect biodiversity of the land because of the lack of pesticides, herbicides, and fertilizers used. A recent meta-analysis from the British Ecological Society indicates that organic agriculture increases species richness by 30% including weeds, plants, organisms, field margins, and natural habitats, in comparison with conventional farming.[26] However, organic agriculture may result in lower productivity, with Seufert et al[1] reporting 34% lower yields compared with conventional agriculture. By incorporating GM technology into organic agriculture, biodiversity and soil quality could be maintained, while increasing product yield through rapid selection.

SUSTAINABILITY OF GMOS AND ORGANIC PRODUCTS

The USDA has established several programs to improve water availability and soil productivity, and limit the effects of climate change. The goals are to reduce the variation in crop production and improve crop resiliency.[4,27] Drought risk has significantly increased in the central United States because of steady rises in average temperatures and precipitation variability.[32] Environmental experts[33–35] project more droughts across the United States (especially in the Rocky Mountain states, Southwestern, and Central Plain regions). Because major US row crops show little evidence of long-run adaptation to climate change, annual yields of crops are predicted to decrease by 15% by 2050,[36] with a clear need for additional drought-tolerant varieties. In 2016, 22% of the US corn acreage was composed of drought-tolerant corn. Drought-tolerant corn use was incentivized by a particularly severe drought in 2013 to 2014. Bioengineering technologies may provide potential solutions for adaptation to drought and climate change and, furthermore, may reduce water consumption.[37]

Population growth, erosion, reduction of fertility, salinization, and desertification of soils have resulted in a net loss of agricultural land. Furthermore, new land can only be cultivated by sacrificing forests.[38] Whereas the yield of crops has been enhanced by means of agrochemicals, organic fertilizers, and biological control use, the widespread use of agrochemicals is causing hazards to human health and the environment.[39] Economists argue[40] that reduced access to GM technology in the United States would result in significantly more land converted from forest to farmland to meet food demand. Using GMO plants with higher yields can help reduce the agricultural environmental footprint without compromising the crop's yield.

In addition to environmental challenges, traditional food production systems face problems with pests, viruses, and diseases. Pesticide use amounted up to 516 million pounds in 2008 in the United States alone.[41] In 1998, GMO corn, cotton, and soybean crops required 3.5% (8.2 million pounds) fewer active pesticide ingredients compared with the traditional crops produced in 1997.[42] Pest- and virus-resistant plant varieties produced in cultivation by GMO breeding could prevent plant disease, halt the massive use of agrochemicals, and extend shelf life. Rainbow and SunUp, papaya ringspot virus–resistant cultivars of the papaya fruit, provide one of the best success stories in the commercialization of a GM fruit crop.[43] Papaya ringspot virus was first reported in Hawaii in the 1940s and was a major threat to papaya industry in 1992. The adoption of transgenic papaya ringspot virus–resistant papaya in Hawaii prevented a disaster in the papaya industry.[44] In addition, conventional breeding (ie, hybridization) of papaya in Hawaii is limited due to several postzygotic incongruities including embryo abortion, poor seed viability, and sterility in progeny.[45] These limitations were overcome by genetic engineering or embryo rescue technologies. Bioengineered papaya, with disease-resistant and extended shelf life traits, have been field tested. Taken together, bioengineering technologies provide a promising solution to directly increasing fruit production and improving fruit sustainability in Hawaii.

ECONOMIC BENEFITS OF GMO TECHNOLOGIES AND THEIR POTENTIAL IMPACTS ON ORGANIC MARKET

The environmental benefits associated with GMO adoption are complemented by a price reduction of agricultural products. Several examples support the view that GM technologies reduce price. The European Union countries are highly dependent on soybean and soymeal imports for animal feed protein sources. Demand is negatively affected because of the slow adoption of GM technology, with most suppliers from the United States, Brazil, and Argentina. The EU experts estimate that soybean prices would increase 200% if imports ceased from their main 3 suppliers.[46] In Romania, Mexico, and Bolivia, where there is a widespread adoption of GM technology for soybean crops, prices fell and profits increased because of second-generation GM technology,[47] resulting in higher income for farmers. Furthermore, GM technology can shorten the farming cycle, which allows farmers to plant additional crops on the same land, leading to additional profits. In a 2010 analysis by the Center for Agriculture and Rural Development at Iowa State University, it was reported that the global production prices of corn, soybean, and canola would be an average of 5.8%, 9.6%, and 3.8% higher, respectively, compared with a 2007 baseline without the use of GM technology.[48] The authors also assert that the price derivatives of soybeans such as meals made from soybean-derived products and oil would increase 5% to 9% without using bioengineering. Taheripour and Tyner[40] assert that the United States would experience a 28% and 22% price increase for non-GMO corn and soybean purchases, respectively, resulting in 14- to 24-billion–dollar cost annually.

North America has the largest organic food market in the world, worth an estimated $48.7 billion. Organic agricultural farmland has grown to include 6.5 million acres of certified organic land in 2018.[49] The benefits of organic agriculture systems go beyond the reduced environmental footprint, to considerably higher profit margins, that is, 22% to 35% more profitable than conventionally grown food, and consumers are willing to pay a premium price of approximately 30% for organic foods.[5] The considerably higher market price is also related to the higher production and labor costs.[50] Organic production scale-up difficulties, in addition to lower yields, result in increases in production costs.

WHY ARE GMOS FORBIDDEN UNDER THE ORGANIC STANDARDS?

The current policy in the US CFR for biotechnology defines approved and prohibited substances to be included in the standards for organic production and handling. In addition, the CFR (Title 7, Subtitle B, Chapter I, Subchapter M, Part 205, Subpart G §205.600) enumerates the evaluation criteria for allowed and prohibited substances, methods of production, and ingredients. The current definition of “excluded methods” shifts GMOs from a product-based to a process-based relationship and continues to limit organic agriculture practices (Organic Trade Association, date unknown).

The CFR for Biotechnology is established by 3 agencies: the USDA's Animal and Plant Health Inspection Service, the Food and Drug Administration, and the EPA. These agencies regulate the planting, transportation, permitting, certification, and safety of GMOs. In 1997, the USDA proposed regulation allowing the inclusion of GMOs in organic agriculture, based on the premise that food safety is related to the properties of the product and not the methods of production.[51] In 2000, the proposal was reviewed and updated in response to more than 275 000 public comments in opposition. In response, the USDA prohibited the use of GMOs in the production and handling of organic products.[52] Consumer pressure is one reason GMOs are prohibited.

ELIMINATING GMOS FROM THE "EXCLUDED METHODS" IS A PROMISING OPPORTUNITY FOR ORGANICS

A main driver for organic agriculture is profitability. However, organic agriculture might have multiple benefits in protecting the health of farm families and communities, as well as adopting environmentally friendly practices.[53] Genetically modified organisms are one path to both profitability and environmental sustainability. A case study for this potential is apple production in the United States. The number of apple farmers and acreage has decreased over the past decades by nearly 25%. Moreover, organic apple yields are reported to be 18% lower than conventional fresh-market apples.[53] Nonetheless, organic apples are one of the top 3 organic fresh fruits purchased by consumers.[53] Health is cited as the primary reason for choosing organic apples.[54] In 1989, when media exposed the wide use of growth regulators in the apple industry, prices declined, resulting in approximately a $140-million loss. The EPA proposed canceling all food uses of the growth regulators, and apple prices rebounded.[53] From this example, lower yields result in higher environmental impacts and higher costs. Second, consumers identify organic products to be healthy, and third, consumers have negative reactions to chemicals use, which drives prices and sales. Supply is one of the main issues the organic industry is facing, limiting the sector's growth.[55] Organic imports have increased, because the demand cannot be met with local products. Thus, use of GMOs in organic agriculture might have multiple benefits in the sector, reducing pesticide use, increasing production, and raising profits.

Legal Hurdles Remain, But They Can Be Overcome

In addition, the limited adoption of organic practices by grain crop growers continues to be a bottleneck for expansion of the US organic livestock sector.[55] Soybean, corn, and canola are the most common applications of GMOs widely used around the world.[56] By allowing GMO technology under the organic standards, soybean, corn, and canola producers could potentially expand their markets to organic feed production without sacrificing yields. Such adoption would drive research to develop GMOs, which address productivity, drought, and pest resistance, and eliminate synthetic herbicide and pesticide use in this potentially very large market. Genetically modified organism grains have been under substantial criticism focused on glyphosates. Organic GMO grain crops would have to be developed under current organic regulations that do not allow for "synthetic" herbicides to be used, thus potentially and perhaps dramatically reducing the use of glyphosates.

Genetically modified technology could enhance options for specialty crop farmers. Although it is still mainly used for extensive monocrops (ie, corn, soybean, and cotton), GM technology has proven potential in specialty crop applications (eg, Rainbow papaya). Moreover, GM technology may assist in crop diversification as a method for adaptation to climate change[57] and provide financial and nutritional security to the farmers by diversifying their income sources.[58,59] Hence, there is a need to incentivize research efforts using GM technology for fruits and vegetables.

SUMMARY

In summary, we believe that consumers reject GMOs for many reasons. Philosophically, many buy organic because they believe organic is somehow less destructive of the environment, and hopefully this is true. Others buy organic because they believe it is the "authentic organic agriculture" of yesteryear, on the basis of marketing assertions involving profitability more than sustainability. Consumers are misinformed about the reality of the existing organic system. Current organic practices are no more "natural" than GM practices. Organic seeds have been highly selected through breeding practices. For example, the organic corn of the 21st century is nothing like the "natural" corn that it was derived from centuries ago. Rigorous and intensive selective breeding and large-scale organic practices mimic and often exceed conventional agriculture in size and resource intensity. Today, "authentic organic farming" is the minority of organic operations. Perhaps with the appropriate use of GMO technology, such authentic systems that work with nature could be expanded, and small local farmers could be supported. Genetically modified organism technology has been misused, and so have intensive selective breeding technologies. Appropriate development of GMOs can be less destructive and support more sustainable agricultural practices. To ignore a valuable opportunity because of past misuse is to repeat historical mistakes.

CONCLUSION

The current policy that GMOs cannot be included in organic food production is outdated. Substantial research since the adoption of the GMO restriction in organic foods has clearly demonstrated safety. Policy change, and if necessary, legislation that allows GMOs to be used in organic farming, and the exclusion of recombinant DNA technology from the definition of "excluded methods" that is presently part of the US CFR are needed. To sustain best practices, food safety should continue to be evaluated on a case-by-case basis, the production of GM seeds should follow the same standards for organic production, and GM products should undergo the same certification methods as traditional organic crops. Genetically modified organisms may provide a sustainable solution to traditional farming by increasing crop yields and decreasing the amount of pesticides and herbicides used. Therefore, GMOs should be allowed to fall within the definition of organic.

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