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Ethical Concerns in Development, Research and Consumption of Genetically Engineered Crops

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Abstract

The commercial application of genetically modified (GM) crops has been one of the major developments of science in the past two decades. Its large-scale proliferation has been driven by lower pesticide costs, higher yields and enhanced nutritional values. Lack of tangible research, however, has brought forth several ethical concerns over the ultimate contribution of this technology. This paper presents the potential benefits and risks associated with GM crops while exploring the various ethical concerns ranging from environmental and economic impacts to consumption of the GM crops. Furthermore, it sheds light onto the extent of research carried out to assess the biosafety of such products and addresses the issues of responsibility raised due to the development and production of GM crops.

Keywords: genetic engineering, genetically engineered crops, biotechnology, ethics, biosafety

Introduction

As world population continues to expand, a relatively slower increase in food production accompanied by higher food prices suggest that survival of humans may depend on the use of genetically engineered crops. These crops are proving to have a number of more favorable characteristics than their "natural" counterparts, which may result in their more widespread use. About 75% of the processed food consumed in the United States contains genetically modified (GM) ingredients (1). At present, GM crops cover at least 10% of the world's farmland, an increase above only 1% when GM crops were first introduced commercially (2). This reliance on GM crops has, however, raised certain ethical concerns regarding potential health effects and environmental impacts. If GM food causes health issues or is gradually affecting the ecosystem in a negative way, how can it be determined and ensured that any risks posed by GM crops have been eliminated or at least minimized? Should producers of GM crops accept responsibility for commercialization of those products not deemed risk-free? Or, should researchers developing genetically engineered plants be held responsible for any such adverse impacts?

In order to evaluate and address the issues and ethical concerns arising from the progressively widespread planting and consumption of GM food, it is first necessary to understand genetic engineering, and how enables production of GM food. According to the *ScienceDaily* website (3), "…a genetically modified food is a food product derived in whole or part from a genetically modified organism such as a crop plant, animal or microbe". In other words, genetically engineered crops are those that have been modified using various biological techniques in an effort to provide new or enhanced features. DNA coding for desired traits is extracted from an organism. The genes of interest are isolated from the DNA and cloned in a host cell. After cloning, the desired genes are modified so as to control and correctly express specific characteristics in the host plant. Copies of this modified gene can then be readied for transformation, in which the gene is inserted into the plant being altered (4). To produce a generation of organisms with particular genetic traits, the organism with the gene(s) of interest is then reproduced. With active functioning of the inserted genes, the organisms are grown and utilized (5). This genetic manipulation results in a genetically modified organism (GMO), which if meant for human consumption, is referred to as a genetically modified food (GMF). Introduction of Bacillus Thuringiensis to make Bt corn is an example of this type of genetic engineering. Bacillus thuringiensis is a bacteria that can encode for a protein that is damaging to insect larvae (6). Upon insertion of the genes that code this protein into corn, researchers have developed a category of corn that generates endogenous pesticides and therefore, are resistant to various insects. Examples of other GM crops include herbicide glyphosphate resistant Bt cotton and Bt potatoes; squash with viral resistance; rice with increased levels of iron and b-carotene (a prominent micronutrient in the production of vitamin A in humans); fast-ripening bananas that facilitate early harvest and long life; tomatoes rich in flavonols, anti-oxidants; drought-resistant and phosphorus-rich corn, and fruits and vegetables containing edible vaccines. (7,8). The advent of GM crop development and production offers new opportunities for greater agricultural productivity, improved nutritional content of food, production of pharmaceuticals and vaccines, and provision of food for the world population. Crops involving genetic alteration will most likely exhibit further development and production in coming years, thereby compelling the utilization of GMF.

Given that the use of genetically engineered crops is relatively new, the long-term effects of this technology have not yet been completely elucidated. The most prominent ethical questions regarding GMOs concern the environmental pollution they might cause, the biodiversity they would threaten, and health risks that might be incurred to various segments of the human and biosphere populations. In addition, ethical debates have been generated relative to intellectual property rights of GM crops and potential corporate control of the food chain (9). This essay approaches some of the ethical issues spawned by genetic engineering of food crops, and explores the extent of research involved in evaluating the safety of such products.

Potential environmental impacts

A major debate regarding GM crops is the potential risk posed to the environment through gene flow. It is claimed that when crops are modified to be herbicide resistant, they can potentially cross-pollinate with other wild plants and produce weeds that will be difficult to control (10). For example, a report published by Greenpeace revealed that herbicide-tolerant crops can trigger the emergence and spread of resistant weeds (10). This would require farmers to increase spray volume and return to older, higher-risk herbicides, thereby increasing potentially negative effect(s) in both costs of production as well as public health problems linked with herbicide use (11). Ongoing debate is now centered upon whether the associated negative effects are significant enough to ban such technology, or if benefits are sufficiently viable so as to engage mechanisms and practices to manage the associated risks.

Another ethical question is whether GM crops could/will disturb the natural ecosystem? It may be that GM crops exhibit an undesirable feature, for example, by becoming invasive or toxic. How will landscape and bio-diversity changes be addressed and managed?

A study at the University of Notre Dame has shown that Midwest streams and rivers were infused with transgenic materials originating from corn crop byproducts, as late as six months after the harvest was done (12). Bt corn, a genetically engineered transgenic product can yield widespread dispersal and presence of corn byproducts in the form of corn leaves, cobs, stalks or husks, and insecticidal proteins present in the genetically engineered corn could affect ecosystems beyond the boundaries of the field (12-14).

This strongly implies that risks accompanying the widespread planting of GM corn were not fully evaluated. This prompts the questions of whether enough research been done to anticipate the effects GM crop byproducts have on aquatic life and the ecosystem, and unanticipated and unwanted effects of such GMFs.

Benefits to the environment

On the other hand, genetically engineered crops exhibit notable benefits. Certain GM crops enable reduced pesticide use thereby decreasing the environmental load and cost incurred by farmers. With crops made resistant to pests and severe weather conditions, crop production can be improved with higher productivity from less field space. Other environmental benefits associated with GM crops have been demonstrated through a Life Cycle

Assessment (LCA) of conventional sugar beet in comparison with GM herbicide-resistant sugar beet (15). This study concluded that "…for a number of environmental and human health impact categories suggest that growing the GM herbicide-tolerant crop would be less harmful to the environment and human health than growing the conventional crop, largely due to lower emissions from herbicide manufacture, transport and field operations. Emissions contributing to negative environmental impacts, such as global warming, ozone depletion, ecotoxicity of water and acidification and nutrification of soil and water, were much lower for the herbicide-tolerant crop than for the conventional crop." Environmental benefits related to reduced pesticide use are of a short duration due to evolution of resistance by the pests. The planting of GM sugar beets could incur insect mutation that might jeopardize niches of other organisms (e.g., birds or bees). What metric(s) can be used to define if benefits are worth the burdens and risks posed to the ecosystem?

On an optimistic note, there have thus far been no reported cases of catastrophic environmental impact due to plantation of GM crops. This, however, does not mean that there have been no environmental effects to date. It could be that the subtle changes to the surrounding wildlife and plants have not been significant enough to draw attention to them or link them to effects of engineered crops. Moreover at present, there are no standard monitoring systems to assess how genetically engineered crops are changing pest resistance. With each crop engineered for a unique purpose, it now becomes important to engage a more casuistic evaluation of the GM crops.

Concerns and ethical issues arising from (human) consumption of GM food

Introducing a new gene into a plant may pose potential risks to human health. For example, it can induce allergic reactions in some individuals (16). Scientists have successfully transferred a gene from Brazil nuts into soybeans in an effort to improve the grain's nutritional quality (17). However, later experiments showed that people allergic to the Brazil nuts were likewise allergic to the transgenic soybean. A study published in the *New England Journal of Medicine (NEJM)* established that "…genetic engineering could transfer an allergen from a certain known allergenic food to another" (18). Another recent study by investigators at the University of Sherbrooke Hospital Centre in Quebec revealed that consumption of crops containing the pesticide-resistant genes from the Bt bacteria have led to the presence of Bt toxin in human blood, that can be passed to fetal blood (19,20). This suggests that the toxin can be passed into subsequent generations, a fact contrary to prior reports that claimed that Bt toxin posed no danger to human health as the protein breaks down in the human gut (21). What is even more concerning is that the long-term health effects of the toxin remain largely unknown. Animal studies, however, have show that consuming the genetically modified corn can prompt development of widely disseminated somatic tumors, as compared to controls that were fed conventional corn (19,22).

The two cases give rise to concerns regarding the research and development of genetically engineered crops. Although, genetically engineered soybeans were not commercialized, what still remains to be addressed is how modified crops can and should be deemed safe for (long-term) human consumption. According to a paper published in Nature, the ideal approach is to use compositional comparisons between GM and non-GM crops (23). If the compositional difference between the two is negligible, they can be regarded as "substantially equivalent" and it can be concluded that the GM crop is "safe for human consumption" (23,24). However, "substantially equivalent" is a somewhat vague concept. There is no specification as to how much difference in composition is acceptable and what features establish it. As well, this method of comparison does not require the industry to execute any level of animal testing, let alone human trials before obtaining patents for GM crops. It is therefore important to query the standard sample size to be used to evaluate if and how the GM crop affects the physiological processes in the human body. Current testing methods that rely solely on chemical analysis of micro or macro nutrients and known toxins are inadequate and may not reveal potential dangers to human health. Indeed, Goodman et al. (25) voice such skepticism and question whether tests being used to assess are scientifically sound.

Paradigmatically, animal testing must be a mandatory step to assess risk. Long-term studies combined with nutritional and toxicological tests should be conducted to evaluate the trans-generational effects of consuming GM foods (compared to non-GM foods). A next step should be validation in clinical trials. Better diagnostic procedures, such as mRNA fingerprinting, proteomics and secondary metabolite profiling (26) are required in addition to more innovative methods for health safety assessment (27,28) so as to screen for even slightly hazardous consequences incurred and to identify these prior to letting a GM crop enter the food chain.

The potential benefits of GM foods promote further research. For example, GM food crops can enhance human nutrition in different regions of the world. One of the most promising GM crops is "golden rice" which can induce increased production of vitamin A (29). In the developing world, mortality due to vitamin A deficiency has been estimated at more than a million children every year, and another half a million exhibit morbidity of permanent blindness (30). Genetically altered rice could decrease mortality and morbidity related to such vitamin A deficiency by as much as 40,000 per year. The promise of such GMF is evident.

Potential threat to economy

Yet, as optimistic as this appears, this promising application of genetically altered crops to combat world hunger gives rise to issues of corporate biopower (31,32). The patent control of these GM crops by multinational corporations may prohibit farmers from re-using seeds for subsequent seasons (31). Traditionally, farmers keep a part of recent harvests to plant as seed for the next season, and trade seeds with other local farmers to practice plant improvement by selecting varieties that have shown desired traits. The advent of GM crops may shift local traditions to the control of corporate politics. This could create an iterative dependence upon GM crops. As a result, small farmers (especially from the developing nations without access to technologies or global markets) will be unable to compete. As noted in the Guardian Weekly (32),"…six giant agrochemical corporations are poised to dominate world food production with genetically engineered food". This could result in widespread re-allocation of farming resources, economic re-organization and frank reliance upon corporate enterprise, and the nations that possess such enterprise — for both agricultural and public health sustainability. Absent a more micro-economically balanced orientation, the profit-driven GM industry will be of benefit to the Western industrial food chain, and in effect will derail motives to promote equity in world markets and societies. Lappé and Bailey claim that leaving this new technology in the sole control of large corporations would allow corporate decision as to what types of genes are to be selected, what type of seeds are to be grown and what pesticides need to be used (33). Here the effects and implications of agricultural and economic biopower become obvious.

Issues of responsibility

At this point, it is necessary to address responsibility fostered by research, development and use of GMOs and GMFs. Simply put, if something goes wrong due to the production or consumption of GM crops, who shall bear responsibility? Furthermore, how should issues of benefit, burden, and risk, in both near and long-term be weighed when addressing the potential value and/or harms of GMO/GMF research and use in developed, developing, and non-developed countries? (See Anderson et al., 2011 for further discussion (34)).

Currently marketed GMFs are not labeled as GM or non-GM substances. As such, if such products are consumed unknowingly — but the product was deemed safe for sale — then consumers would in no way be responsible. In such cases, responsibility could be placed on the manufacturers for selling (unsafe) crops. The responsibility of the manufacturers would, however, depend upon awareness of the harm of their products. If manufacturers were cognizant of harms and still marketed the product, then there is clear assumption of (ethico-legal) responsibility. On the other hand, if manufacturers were unaware of potential hazards, the issue of responsibility could be somewhat more contestable. Ultimately, such claims of responsibility fortify a stance of *caveat emptor* — let the consumer be wary — at least at this point in the development and promulgation of GMOs and GMFs.

Conclusion

A major point is that genetically engineered crops do have benefits as well as possibly harmful effects on humans and the environment. A blatant solution to the ethical issues posed may be avoiding consumption of GM Foods. However, in the long run, this does little to leverage current- and near future scientific and technologic capabilities to stem the very real problem of world hunger and agricultural ecology and economics in developing countries. Thus, a viable posture would be to proceed with caution. Research on GM crops must advance, but at the same time be co-focused upon their effects on human and animal health, and the environment. Each GM crop much be analyzed on a case-by-case basis, and improved testing methods need to be established and implemented before any product is brought to market (as post-marketing monitoring is significantly more expensive and thereby difficult (35). Safety assessment should be made entirely transparent, acknowledged and be open to public scrutiny.

GM products should be labeled (35) to empower consumer's freedom to choose from GM and non-GM foods. Ongoing discourse- on formal and multi-national levels- must address issues of a gradual dependence on the GM manufacturers and corporate responsibilities arising from GMOs and GMFs. Clearly, GMOs and GMFs will be a resource and commodity through which purchase may be gained in issues of global agriculture and hunger. What remains at the fore is how the price of such purchase will be addressed and managed.

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