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Genetic Modification of Food

New methods of agricultural production must be utilized if the additional two billion people expected to populate the world over the next 30 years are to be fed. And, this must be done in the face of the world's natural resource base becoming increasingly fragile (FAO, 2003: 3). Technologies are becoming available to further increase food production and conserve our natural resources, continuing the advances made in this field during the past century.

One of the advances made during the past century was the invention of synthetic nitrogen fertilizer. At the time of this important discovery, Europeans and North Americans were mining guano and nitrates around the world to provide nutrients for their agriculture and food production. These resources of nitrogen were becoming exhausted and increasingly scarce (DeGregori, 2002: 139). They needed to add nitrogen to replenish their fallow fields and synthetic nitrogen was the answer. “One might not call the Haber-Bosch synthesis of nitrogen fertilizer the greatest invention of the twentieth century as Valclav Smil has done, but it would be difficult to argue against him, as we simply could not have fed even half the worlds population today without it” (DeGregori, 2004: 128). The technologies of the past enabled us to produce higher-yielding seeds and gave us the inputs required to make them grow and just as technology saved the population of today from massive food shortages; it will undoubtedly play a major role in helping the people of tomorrow (FAO, 2003: 3).

It would be nice to have an increase in agricultural production --enough to feed a yet to be world of 9 billion humans-- without an environmental cost, but that is simply not possible. It is possible, however, to reduce the environmental cost of increasing agricultural production (DeGregori, 2002: 145, 166). DeGregori goes on to contend that, “Without a continuing flow of new technology, forest and wildlife preserves could be lost to agricultural expansion with the ever increasing possibility of species extinction and consequent loss of biodiversity” (2004: 129). In fact, new transgenic biotechnology can provide various food crops that have the potential to increase yields by decreasing the damage caused by pest infestations, while reducing chemical usage. The reduced chemical usage by farmers can reduce environmental damage caused by agriculture production. Not only do these transgenic crops have the potential to reduced environmental damage they also have the potential of growing despite abiotic stresses (e.g. aluminum, salt, and drought), all the while providing more nutrition to consumers (FAO, 2003: 72,). Considering where technology has taken us and where we are headed, it is logical to assume that “plant biotechnology is not simply a luxury but increasingly a necessity” (DeGregori, 2004: 130). Transgenic technology is a tool that has the potential to ease our future woes.

Genetic modification of food is often a misunderstood phrase. Almost every crop we use as a source of food has undergone some type of genetic modification. Our ancestors searched for crop plants, utilizing the ones that survived insect infestation. By using and planting the seeds, they unknowingly were selecting crops with better resistance to pest. By cross breeding their selections, humans modified crops to be more productive and heartier as well as for specific features such as faster growth, larger seeds, and sweeter fruits. It is understood that “Farmers and pastoralists have manipulated the genetic make-up of plants and animals since agriculture began more than 10,000 years ago. Farmers managed the process of domestication over millennia, through many cycles of selection of the best-adapted individuals. This exploitation of the natural variation in biological organisms has given us the crops, plantation trees, farm animals and farmed fish of today, which often differ radically from their early ancestors” (FAO, 2003: 9).

The first major insight into the science of breeding plants was in 1865 when Gregor Mendel, the father of genetics, explained how dominant or recessive alleles could produce the traits we see and that these traits could be passed to offspring. Plant breeding advanced in the wake of Mendel's discovery. Breeders introduced their new comprehension of genetics to the established methods of self-pollinating and cross-pollinating plants. It was not long before plant breeders discovered that, during the natural evolution of plants, spontaneous mutations would occur. Some of these mutations produced desirable and sought after traits. However, the natural rate of spontaneous mutation was unreliable not to mention very slow (CSU, 2004: A).

Researchers and plant breeders wanted to find a way to tap into this process. Their goal was to induce mutations so they could quickly create better varieties of food. As science progressed from the late 1920’s into the 1970’s, researchers were genetically modifying foods with induced mutations (CSU, 2004: A). They induced mutations by exposing plant parts with chemical or physical mutagens effectively mimicking spontaneous mutations (FAO, 2003: 10). Some of this mutation breeding involved “deliberately bombarding plants or their seeds with radiation with the intention of creating mutations” (DeGregori, 2002: 126). With out mutations, there would be no rice, or maize or any other crops, as we know them (FOA, 2003: 10). In fact, over two thousand two hundred varieties of mutant crops have been officially released to date; all of them beneficial and without the slightest evidence of harm (DeGregori, 2002: 127).

Despite the successfulness of genetic modification by the conventional breeding techniques discussed so far, many generations of breeding are needed to isolate the desirable traits and minimize the undesirable traits. Through the research of the 80’s and 90’s we know that “biotechnology can make the application of conventional breeding methods more efficient” (FAO, 2003: 9). With biotechnology, we can transfer desired traits into plants faster and more selectively by transplanting the specific desired gene into the crop plant.

As these biotechnology procedures developed, the terms genetic modification, genetically engineered, genetically modified and transgenic have become interchangeable terms in today’s society. When most people speak of genetically modified foods, they are actually referring to transgenic foods. We will use those terms interchangeably through the rest of this paper. A transgenic crop plant has a gene or genes artificially acquired as opposed to acquiring them through pollination. The gene that has been successfully transferred by artificial insertion is known as the transgene. The transgene can come from a different species of plant or from an organism that is from a completely different kingdom (CSU, 2004: B). This is useful in situations “When the desired trait is found in an organism that is not sexually compatible with the host, it may be transferred using genetic engineering” (FOA, 2003: 15). Genetic modification is seen as a more precise extension of conventional approaches to modifying plants and “At the same time, genetic engineering can be seen as a dramatic departure from conventional breeding because it gives scientists the power to move genetic material between organisms that could not be bred through classical means” (FAO, 2003: 22).

“Three distinctive types of genetically modified crops exist: (a) ‘distant transfer’, in which genes are transferred between organisms of different kingdoms (e.g. bacteria into plants); (b) ‘close transfer’, in which genes are transferred from one species to another of the same kingdom (e.g. from one plant to another); and (c) ‘tweaking’, in which genes already present in the organism's genome are manipulated to change the level or pattern of expression. Once the gene has been transferred, the crop must be tested to ensure that the gene is expressed properly and is stable over several generations of breeding. This screening can usually be performed more efficiently than for conventional crosses because the nature of the gene is known, molecular methods are available to determine its localization in the genome and fewer genetic changes are involved” (FAO, 2003: 16).

“Neither of the major food grains – wheat and rice – currently have transgenic varieties in commercial production anywhere in the world” (FAO, 2003: 38). “The most widely grown transgenic crops are soybeans, maize, cotton and canola” (FAO, 2003: 38). Other types of transgenic crops that are being cultivated commercially include very small quantities of virus-resistant papaya and squash, but most of the transgenic crops planted so far have incorporated only a very limited number of genes aimed at conferring insect resistance and/or herbicide tolerance (FAO, 2003: 17).

Bt-corn is one common example of a genetically modified crop that resists pest and is also less likely to be infested (30 to 40 times lower) with Fusarium ear rot, a fungal infection that produces toxins, called fumonisins, which are often fatal to pigs and horses and can cause esophageal cancer in humans (DeGregori, 2002: 12). The Bt gene in Bt-corn is acquired from the Bacillus thuringiensis bacteria. Sprays and powders that are comprised of this Bt bacterium have been, and continue to be, used regularly for pest management. When scientists create Bt-corn, they start by selecting a strain of corn for the Bt transformation that has agronomic qualities for yield, harvest ability and natural disease resistance. Next, they identify a strain of Bt that will destroy the chosen insect. The Bt gene that generates the pesticide protein is detached and connected to another gene (the resistant gene) that has been isolated for its resistance to a herbicide. The newly attached genes are inserted into the pre-selected corn plant cells. The scientists then locate the plant cells that contain both the Bt gene and its connected resistant gene. Not all of the plant cells will have transformed in this way, so it is important for them to find those two genes still attached to one another. The plant cells that meet the criteria are then grown in the presence of the herbicide. The cells that are not affected by the herbicide are taken and grown into whole plants, by a process called tissue culture. Those plants go on to produce a protein that is deadly to the targeted insects and corn bores. Successive generations will also inherit the insect resistant features (CSU, 2004: A, B, C, D).

Specifically, “Bioengineered Bt (Bacillus thuringiensis) corn has a protein that is activated by enzymes in the insect gut when ingested by the corn bore or other insect pest. The activated Bt protein binds to specific receptor sites in the gut and inserts itself into the membrane of the insect gut. Bound to the inner linings of the stomach, the Bt toxin causes a influx of water into cells that swell and destroy the insect digestive system (Nester et al. 2002). ‘As the gut liquid diffuses between the cell, paralysis occurs, and bacterial invasion follows’ (Benarde 2002, 117). This leads to insect starvation and eventual mortality and is the same mechanism used by the live Bacillus thuringiensis bacteria to kill the insect and then feed and multiply on its remains” (DeGregori, 2004: 109).

This Bt protein is not toxic to humans because it is broken down in the digestive system. The stomachs of mammals are acidic, while those of insects are alkaline. The Bt’s crystalline protein is alkaline, and consequentially the receptor sites for this protein are lacking in an acidic environment, rendering the Bt harmless to all but insects (DeGregori, 2004: 109).

By allowing the corn and other crops to produce their own pesticides and herbicides through genetic modification, we have shifted the traditional focus of agriculture from one of trying to produce higher yields, to one that also includes a lower environmental impact. "The scientific consensus is that the use of transgenic insect-resistant Bt-crops is reducing the volume and frequency of insecticide use on maize, cotton and soybean" (ICSU, cited in FAO, 2003: 69). There are several positive effects resulting from reduced pesticide spraying. One is that field workers are protected from exposure to pesticide poisons. Another positive result is that pesticide runoff into water supplies is reduced with a reduction in pesticide application. In addition, less pesticide spraying causes less damage to non-target insects. "Reduced pesticide use suggests that Bt-crops would be generally beneficial to in-crop biodiversity in comparison with conventional crops that receive regular, broad-spectrum pesticide applications, although these benefits would be reduced if supplemental insecticide applications were required" (GM Science Review Panel, cited in FAO, 2003: 69).

The fact is, "Scientist agree that the use of conventional agricultural pesticide and herbicide has damaged habitats for farmland birds, wild plants and insects and has seriously reduced their numbers" (FAO, 2003: 68). Along with insect resistant crops, it is speculated that herbicide tolerant crops have the potential to promote biodiversity as well. If changes in herbicide use allow weeds to remain for longer periods of time it would provide habitat for birds and other species. Herbicide tolerant crops also would enable the use of less toxic forms of herbicide and encourage the adoption of low till crops that result in benefits for soil conservation by conserving soil that is more easily eroded when fields are conventionally cultivated (FAO, 2003: 69).

Scientists concede that more studies are needed which compare conventional agricultural practices with the agricultural practices that utilize transgenic crops (FAO, 2003: 68). Because large-scale cultivation of transgenic crops is a newer technology, the effects of crop production on the environment are still emerging. As with any type of agriculture, whether conventionally done or not, there are adverse affects to the environment. The idea is to minimize the adverse affects while maximizing the benefits.

Experts agree that changes in agricultural practices, such as herbicide and pesticide use, due to transgenic crops may have positive or negative indirect environmental effects depending on how and where they are used (FAO, 2003: 66). However, it is currently acknowledged that, "Negative environmental consequences, although meriting continued monitoring, have not been documented in any setting where transgenic crops have been deployed to date" (FAO, 2003: 57).

There is concern that long-term use of herbicide tolerant Bt-crops will lead to insects and weeds that are resistant to glyphosate and gluphosinate, the herbicides associated with these crops (FAO, 2003: 71). "Similar breakdowns have routinely occurred with conventional crops and pesticides and, although the protection conferred by Bt genes appears to be particularly robust, there is no reason to assume that resistant pests will not develop" (GM Science Review Panel, cited in FAO, 2003: 71).

The expected development of resistant pest and weeds has led scientists to advise that farmers implement a resistance management strategy when they plant transgenic crops (FAO, 2003: 72). The proliferation of insects that can resist Bt technology would be considered an environmental set back because the use of more toxic forms of chemical control would be needed to get rid of the pest.

The U.S. Environmental Protection Agency, which regulates Bt-crops because of their pesticidal classification, agrees with scientist recommendations regarding the need for a resistance management strategy. The U.S. Environmental Protection Agency requires farmers who plant Bt-crops to include refuges. An example of a refuge is a block of non-Bt-corn planted near a Bt-cornfield (EPA, 2004). "EPA requires all farmers who use Bt-crops to plant a portion of their crop with such a refuge. The aim of this strategy is to provide an ample supply of insects that remain susceptible to the Bt toxin. The non-Bt refuge will greatly decrease the odds that a resistant insect can emerge from a Bt field and choose another resistant insect as a mate. The likelihood that two insects with a resistant gene will find each other and mate is greatly decreased" (EPA, 2004).

It is debatable how effective this system can be, considering it is dependent on farmers complying with the requirements to plant enough refuges. The data collected by the Department of Agriculture's National Agricultural Statistics Service, showed that nineteen percent of all Bt-corn farmers in Iowa, Minnesota, and Nebraska, roughly 10,000 farms, violated the Environmental

Protection Agency's refuge requirements in 2002. Thirteen percent of farmers growing Bt-corn planted no refuges at all. Although most farmers that grow Bt-crops plant enough refuges, those that do not need to meet their obligations so that the benefits of this agricultural biotechnology will not be squandered (CSPI, 2003).

There are issues concerning the coexistence of non-transgenic crops (organic and conventional) and transgenic crops. Transgenic crop farmers that use Bt-crops and do not comply with resistance management strategies increase the possibility those insects will develop immunity to Bt. The Bt soil bacterium is sometimes used by non-genetically modified crop farmers to protect their crops from insect infestations, and Bt resistant insects will cause these farmers to lose Bt spray as an effective deterrent (Cummins, 2004).

In addition, some people want to avoid eating foods that contain transgenes, even though genetically modified crops are as safe to eat as their non-genetically engineered counterparts are. Most people would agree that we should not "interfere with the rights of others" (DeGregori, 2004: 61). However, people might not be able to avoid transgenic crops because wind, birds and other pollinators can carry genetically altered pollen into non-genetically modified crop fields, resulting in a hybridized seed that will contain genetically modified DNA (Cummins, 2004).

This gene flow from genetically modified crops could make non-transgenic farming very difficult. Currently, "Management and genetic methods are being developed to minimize the possibility of gene flow" (FAO, 2003: 67).

Artemio Salazar suggest that one possible way to avoid cross pollination is by employing temporal isolation by planting Bt-crops 25 days before or after the non-Bt-crops are planted (Pabico, 2003). "This is the same method used to avoid cross-pollination between white and yellow corn varieties" (Pabico, 2003). Another possible way to slow the gene flow of genetically modified pollen is to plant a buffer zone of trees around the field and have the different crops isolated by an appropriate distance (CBC, 2002). One of the most promising developments is that "Genetic engineering can be used to alter flowering periods to prevent cross-pollination or to ensure that the transgenes are not incorporated in pollen and developing sterile transgenic varieties" (ICSU and Nuffield Council cited in FAO, 2003: 67).

The safety of genetically modified food to human health has always been a concern. "The main food safety concerns associated with transgenic products and foods derived from them relate to the possibility of increased allergens, toxins or other harmful compounds; horizontal gene transfer particularly of antibiotic-resistant genes; and other unintended effects. Many of these concerns also apply to crop varieties developed using conventional breeding methods and grown under traditional farming practices" (FAO, 2003: 59).

The allergens and toxins can be controlled more effectively in genetically modified foods because the uses of genes from known allergenic sources are discouraged and the genetically modified foods are rigorously tested for such substances. Traditionally developed foods are not generally tested for these substances even though they often occur naturally (FAO, 2003: 60).

The transfer of antibiotic-resistant genes has been addressed. Many had been concerned about antibiotic resistant bacteria being transferred from genetically modified food to humans. This concern arose from the early days when genetically modified crops were created using antibiotic-resistant marker genes. The possibility existed for those genes to pass from the food product into the cells of humans. Therefore, development of antibiotic-resistant strains of bacteria could have resulted (FAO, 2003: 60). In response, "researchers have developed methods to eliminate antibiotic-resistant markers from genetically engineered plants" (FAO, 2003: 60).

To ease safety concerns, genetically modified foods should be continuously evaluated for safety. Any new transgenic creations need to be assessed with caution even though "the best scientific testing can find no evidence of harm and nothing in our current scientific knowledge gives us any reason to expect to find harm by continued testing" (DeGregori, 2004: 83). There is potential for harm in organic or conventional plant breeding and there is no evidence genetically modified foods are less safe. The genetically modified foods might even be safer than conventional crops when you consider that "With transgenic, conventional farmers will be able to produce a crop as close to being truly pesticide-free (the only pesticide possibly being a gene that expresses a protein toxic only to specific pest) as has ever been done by humans" (DeGregori, 2004: 90).

DeGregori asserts that with crop protection built into transgenic crops there will be little question as to which crop, conventional or organic, has the fewest toxins, either applied by the farmer or produced by the plant (2004: 90). It is worth noting that "Although the international scientific community has determined that foods derived from the transgenic crops currently on the market are safe to eat, it also acknowledges that some of the emerging transformations involving multiple transgenic may require additional food-safety risk-analysis procedures" (FAO, 2003: 4).

The future holds other possibilities for transgenic foods besides just incorporating genes aimed at insect resistance and/or herbicide tolerance. "Modern biotechnology has the potential for bringing previously degraded lands back into cultivation with, for example, salt tolerant plants that could be cultivated on lands salinated by centuries of irrigation. This would also relieve or reduce pressure to bring other lands under cultivation" (DeGregori, 2002: 141). Similar works in progress are to improve the tolerance of plants to other environmental stresses such as temperature extremes. Scientist are developing wheat with improved tolerance to aluminum because thirty percent of all arable land is not suitable for plant growth due to aluminum in acid soils (FAO, 2003: 9, 16). In addition, "Biotechnologists are working to create even more efficient plants, including the use of water" (DeGregori, 2004: 134). There is even the possibility of creating crops that have nutritional enhancement. For instance, with rice we are "fast approaching a theoretical limit set by the crop's efficiency in harvesting sunlight and using its energy to make carbohydrates" (Surridge 2002, 576 cited in DeGregori, 2004: 130). "Improving the photosynthetic efficiency of rice has the potential of increasing nutritional value and enhancing its ability to withstand environmental stress" (DeGregori, 2004: 131). "The well-known transgenic Golden Rice contains three foreign genes - two from the daffodil and one from a bacterium - that produce provitamin A. Scientists are well on their way to developing transgenic 'nutritionally optimized' rice that would contain genes producing provitamin A, iron and more protein. Other nutritionally enhanced foods are under development, such as oils with reduced levels of undesirable fatty acids. In addition, foods that are commonly allergenic (shrimp, peanuts, soybean, rice, etc.) are being modified to contain lower levels of allergenic compounds" (FAO, 2003: 17).

Public attitudes on transgenic food are as diversified and complex as the individuals that make up society. "It is apparent that few people express either complete support for or complete opposition to biotechnology" (FAO, 2003: 84). Studies show that attitudes are related to income levels.

Although there are exceptions, wealthy counties have more views that are negative with regard to genetically modified food than those of poorer countries. "In general, people in higher income countries tend to be more skeptical of the benefits of biotechnology and more concerned about the potential risk" (FAO, 2003: 77). Public support for genetically modified food differs widely when considering the application of such technology. For instance, applications that address health and environmental concerns where looked upon more favorably than applications promoting an increase in agricultural production (FAO, 2003: 78).

Most people know very little about transgenic foods. The public's main source of information on the subject is through news media like television or newspaper. This lays great responsibility on companies that run these information sources to get accurate information out to the public. Unfortunately, these media outlets are prone to report studies that result in negative findings regarding genetic modification technologies.

Even when those same studies are peer reviewed and found to be inaccurate, there is usually no follow up to report the facts. The result is a misinformed public.

A good example of this would be the monarch butterfly controversy. In 1999, a Cornell University entomologist named John Losey published a research paper, in the scientific journal *Nature*, claiming monarch butterfly larvae died after eating milkweed leaves dusted with Bt-corn pollen. The paper immediately ignited a worldwide controversy and led to intense news coverage that promoted the supposed dangers of agricultural biotechnology. The New York Times even ran a front-page story on the topic (FAO, 2003: 71).

Contrary to much publicity and street theater, the monarch butterfly is unharmed by ingesting the Bt protein at levels in which it is naturally exposed to in the wild (DeGregori, 2004: 117). Six independent teams of researchers conducted follow-up studies that discredited Loseys findings and showed that Bt-corn posed less risk to monarch butterfly larvae than conventional pesticides (FAO, 2003: 71).

None of the TV or newspaper media, excluding The New York Times, did follow up reporting. The New York Times obscured their follow up story in the back pages. These types of irresponsible media coverage (or lack of coverage) have contributed to public confusion. “Many scientists are frustrated by the way the monarch butterfly controversy and other issues related to biotechnology were handled in the press. Although the original monarch butterfly study received worldwide media attention, the follow up studies that refuted it did not receive the same amount of coverage. As a result, many people are not aware that Bt maize poses very little risk to monarch butterflies” (Pew Initiative, 2002 cited in FAO, 2003: 71).

People forget that several US governmental agencies and numerous others in the scientific community have tested the transgenic crops that are commercially grown and all of them have concluded that transgenic crops are as safe (or safer) than their conventional counterparts. The evolution of genetic modification in plant breeding has the potential to increase yields while decreasing pest infestations, reduce chemical use, relieve stresses such as aluminum, salt, and drought and make foods more nutritious.

There will actually be no reasonable alternative to the use of new technology to feed the world's population three decades from now, which will be greater than it is today by more than two billion individuals. Despite the capabilities of technology, there will be resistance to the production of foods that contain transgenes. Ironically, most of the resistance will be from wealthier countries where the advances in technology most often occur. Promoters of foods that contain transgenes will face opposition in two ways. One is through restrictions placed on their work by government, thereby delaying progress and increasing costs. The other is through misinformation spread by those opposing foods with transgenes. The spreading of misinformation will cause people to refuse to buy food that contains transgenes. In either case, the best way to promote foods that contain transgenes will be to emphasize the benefits to health and the environment, not increased yields brought on by the production of transgenic agricultural products.

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