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Review Article

A Review on Concerns and Benefits of Genetically Modified Organisms

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Abstract

The enhancement of desired traits has traditionally been undertaken through breeding, but conventional plant breeding methods can be very time consuming and are often not very accurate. Genetic engineering, on the other hand, can create plants with the exact desired trait very rapidly and with great accuracy for the betterment of society through development of crops with improved nutritional quality, resistance to pests and diseases, and reduced cost of production. Although this method is more efficient, critics fear that the result — a "novel gene combination" — may have health or environmental impacts that are not being adequately addressed. As a result; the technology is surrounded by significant controversy especially in the areas of safety testing, regulation, international policy and food labeling. Intensive studies have been made concerning the benefits and concerns of GMO that means biotechnology offers a variety of potential benefits and risks. These studies indicated that the techniques have to been proceed with caution to avoid causing unintended harm to human health and the environment as a result of our enthusiasm for this powerful technology. Generally, Biotechnology, in the form of genetic engineering, is a facet of science that has the potential to provide important benefits if used carefully and ethically.

Keywords: *Bacillus thuringiensis,* Biotechnology, Genetic engineering**,** genetically engineered organisms,

Introduction

Biotechnology is a rapidly developing field that, in an attempt to meet the current and emerging challenges facing agriculture – such as poor nutrition, unstable and limited food production, and restricted fuel availability – has received considerable investment for the improvement of major crops [28, 24, and 26]. Although many consider biotechnology to be synonymous with genetic modification (GM), this is only one part of a wider field of application [17, 8, and 30].

Opportunities and constraints in agricultural biotechnology are of significance in responding to the challenge of poverty in the 21st century [21] as they influence the development of national strategies that minimize environmental, health and social risks; and that address the nutritional needs of poor resource farmers.

The agriculture industry has traditionally been supportive of technological advancement, particularly in the field of genetic crop improvement [29]. For decades; the industry has been mixing naturally the genetic traits of seeds in the search for particularly robust varieties. Profit-oriented agricultural biotechnology is now addressing poverty, food insecurity, conservation of the environment, and sustainable development [14].

Genetic engineering is the process of changing the genetic material of living organism to produce some desired change in that organism's characteristics. This process is often used to develop new plant and animal varieties that are later used as sources of foods, referred to as genetically engineered foods or genetically modified organisms. The enhancement of desired traits has traditionally been undertaken through breeding, but conventional plant breeding methods can be very time consuming and are often not very accurate. Genetic engineering, on the other hand, can create plants with the exact desired trait very rapidly and with great accuracy. For example, plant geneticists can isolate a gene responsible for drought tolerance and insert that gene into a different plant. The new genetically-modified plant will gain drought tolerance as well. Not only can genes be transferred from one plant to another, but genes from non-plant organisms also can be used [2]. The best known example of this is the use of B.t. genes in corn and other crops. B.t., or *Bacillus thuringiensis,* is a naturally occurring bacterium that produces crystal proteins that are lethal to insect larvae. B.t. crystal protein genes have been transferred into corn, enabling the corn to produce its own pesticides against insects such as the European corn borer.

Genetically modified (GM) crops have been widely adopted, with approximately 114 million ha cultivated in 23 countries worldwide in 2007 [12]. The first commercially successful GM traits were herbicide and insect resistance traits that provided alternatives to conventional chemical pesticides or mitigated crop yield losses [2]. Some of the most common GE crops include varieties of corn and soybeans. In 2011, 88 percent of all corn and 94 percent of all soybeans produced in the U.S. were grown from GE seeds [3]. Other common GE crops include alfalfa, canola, cotton, papaya, sugar beets, and zucchini. In addition, GE crops are used to make food ingredients (such as high fructose corn syrup) that are often included in processed foods (meaning foods that are not raw agriculture crops).

Although this method is more efficient, critics fear that the result — a "novel gene combination" — may have health or environmental impacts that are not being adequately addressed [28]. As a result; the technology is surrounded by significant controversy. Therefore, this paper describes the benefits that GM organisms can provide to farmers, as well as the concerns that farmers should address before utilizing these organisms. It is intended only as a general introduction to these benefits and concerns.

Benefits

Everything in life has its benefits and risks, and genetic engineering is no exception. Much has been said about potential risks of genetic engineering technology, but so far there is little evidence from scientific studies that these risks are real. Transgenic organisms can offer a range of benefits above and beyond those that emerged from innovations in traditional agricultural biotechnology. Ensuring an adequate food supply for the booming population is going to be a major challenge in the years to come. GM foods promise to meet this need in a number of ways.

Following are a few examples of benefits resulting from applying currently available genetic engineering techniques to agricultural biotechnology.

Increasing crop productivity

Biotechnology has helped to increase crop productivity by introducing such qualities as disease resistance and increased drought tolerance to the crops. Now, researchers can select genes for disease resistance from other species and transfer them to important crops. For example, researchers from the University of Hawaii and Cornell University developed two varieties of papaya resistant to papaya ringspot virus by transferring one of the virus' genes to papaya to create resistance in the plants. Seeds of the two varieties, named 'SunUp' and 'Rainbow', have been distributed under licensing agreements to papaya growers since 1998.

Further examples come from dry climates, where crops must use water as efficiently as possible. Genes from naturally drought-resistant plants can be used to increase drought tolerance in many crop varieties.

Increasing crop yield is an expectation widely held by those in agriculture that GM seeds will increase the yields of farmers that adopt the technology. Although there is not yet a large volume of research regarding the impact of biotechnology on crop yields and returns, the research that is available supports this expectation. In a study using 1997 data, the Economic Research Service (ERS) found a statistically significant relationship between increased crop yields and increased adoption of herbicide- and pesticide-tolerant crop seeds [10]. The ERS study found that crop yields "significantly increased" when farmers adopted herbicide-tolerant cotton and Bt cotton [10]. The use of herbicide-tolerant soybeans resulted in a "small increase" in crop yields. Another study performed by Iowa State University found that Bt crops out-yielded non-Bt crops. The university studied 377 fields and estimated that crops grown from GM seeds yielded 160.4 bushels of Bt corn per field, while crops grown from non-GM seeds yielded 147.7 per field.

Enhanced crop protection

Farmers use crop-protection technologies because they provide cost-effective solutions to pest problems which, if left uncontrolled, would severely lower yields. As mentioned above, crops such as corn, cotton, and potato have been successfully transformed through genetic engineering to make a protein that kills certain insects when they feed on the plants. The protein is from the soil bacterium *Bacillus thuringiensis*, which has been used for decades as the active ingredient of some "natural" insecticides.

In some cases, an effective transgenic crop-protection technology can control pests better and more cheaply than existing technologies. For example, with *Bt* engineered into a corn crop, the entire crop is resistant to certain pests, not just the part of the plant to which *Bt* insecticide has been applied. In these cases, yields increase as the new technology provides more effective control. In other cases, a new technology is adopted because it is less expensive than a current technology with equivalent control.

There are cases in which new technology is not adopted because for one reason or another it is not competitive with the existing technology. For example, organic farmers apply *Bt* as an insecticide to control insect pests in their crops, yet they may consider transgenic *Bt* crops to be unacceptable.

Crop plants genetically-engineered to be resistant to one very powerful herbicide could help to prevent environmental damage by reducing the amount of herbicides needed. For example, Monsanto has created a strain of soybeans genetically modified to be not affected by their herbicide product Roundup. A 2010 study has found that long-term exposition to environmental relevant concentrations of a Roundup formulation causes metabolic disruption in *Leporinus obtusidens* [22]. A farmer grows these soybeans which then only require one application of weed-killer instead of multiple applications, reducing production cost and limiting the dangers of agricultural waste run-off [19].

Fewer applications of pesticides and herbicides

Farmers typically use many tons of chemical pesticides annually. Consumers do not wish to eat food that has been treated with pesticides because of potential health hazards, and run-off of agricultural wastes from excessive use of pesticides and fertilizers can poison the water supply and cause harm to the environment. Growing GM foods such as B.t. corn can help to eliminate the application of chemical pesticides and reduce the cost of bringing a crop to market [15].

The study by ERS found a decrease of pesticide and herbicide use when farmers adopted GM seeds. The decrease in pesticide use was significant [10]. This decrease in herbicide use was also significant (except for the herbicide glysophate, for which the research revealed a significant increase) [10]. Other studies have not found a clear connection between the use of GM seeds and decreased chemical use. For instance, the Iowa State University study discussed above found that farmers' use of pesticides on GM crops remained "surprisingly large." Farmers applied pesticides on 18% of non-GM crops and 12% of GM crops [22].

Increased profits

In general, studies indicate that farmers' profits increase as they adopt GM seeds. The ERS study found that in most cases there is a statistically significant relationship between an increase in the use of GM seeds and an increase in net returns from farming operations [10]. For example, the service found that, on average, GM soybean crops produced a net value of $208.42 per planted acre, while other crops produced a value of $191.56 per planted acre [10]. The service also found a "significant increase" in net returns for herbicide-tolerant cotton crops and Bt cotton crops. Other studies have reached similar results. Studies in Tennessee and Mississippi found higher returns from herbicide-resistant soybeans than from conventional soybeans. A North Carolina study indicated that GM soybeans yielded $6 more per acre than traditional varieties [7].

Environmental benefits

When genetic engineering results in reduced pesticide dependence, we have less pesticide residues on foods, we reduce pesticide leaching into groundwater, and we minimize farm worker exposure to hazardous products. With *Bt* cotton's resistance to three major pests, the transgenic variety now represents half of the U.S. cotton crop and has thereby reduced total world insecticide use by 15 percent! Also, according to the U.S. Food and Drug Administration (FDA), "increases in adoption of herbicide-tolerant soybeans were associated with small increases in yields and variable profits but *significant decreases* in herbicide use".

Biotechnology is also providing opportunities to decrease soil erosion because some biotech crops require less tilling, helping to preserve topsoil and reduce runoff into streams and rivers and provide habitat for wildlife. This may allow farmers to have fewer tractor passes over their fields – conserving fossil fuels. In some areas, crops genetically modified for herbicide tolerance could decrease the amount of herbicide used and allow for no-till agriculture, which can minimize erosion. The reduced pesticide and herbicide use on biotechnology crops results in a cleaner, better environment for all.

Improved nutritional value

Genetic engineering has allowed new options for improving the nutritional value, flavor, and texture of foods. Transgenic crops in development include soybeans with higher protein content, potatoes with more nutritionally available starch and an improved amino acid content, beans with more essential amino acids, and rice with the ability produce beta-carotene, a precursor of vitamin A, to help prevent blindness in people who have nutritionally inadequate diets.

Researchers at the Swiss Federal Institute of Technology Institute for Plant Sciences have created a strain of "golden" rice containing an unusually high content of beta-carotene (vitamin A) [20]. Plans were underway to develop golden rice that also has increased iron content.

Benefits for developing countries

Genetic engineering technologies can help to improve health conditions in less developed countries. Researchers from the Swiss Federal Institute of Technology's Institute for Plant Sciences inserted genes from a daffodil and a bacterium into rice plants to produce “golden rice,” which has sufficient beta-carotene to meet total vitamin A requirements in developing countries with rice-based diets. This crop has potential to significantly improve vitamin uptake in poverty-stricken areas where vitamin supplements are costly and difficult to distribute and vitamin A deficiency leads to blindness in children.

Possible risks associated with using transgenic crops or genetically modified organisms

According to many scientists and crop producers, there are many benefits in applying biotechnology in the food industry. Its benefits include the possibilities of solving the world's hunger problem, introducing super food with added vitamins and nutrients and improving economic growth [13]. However, the production of genetically modified foods (GMF) and crops has also raised ethical questions. Modern technology such as biotechnology has been criticized for its application and unknown impacts on human health and environment [9]. Some consumers and environmentalists feel that inadequate effort has been made to understand the dangers in the use of transgenic crops, including their potential long-term impacts. Some consumer-advocate and environmental groups have demanded the abandonment of genetic engineering research and development. Many individuals, when confronted with conflicting and confusing statements about the effect of genetic engineering on our environment and food supply, experience a “dread fear” that inspires great anxiety. This fear can be aroused by only a minimal amount of information or, in some cases, misinformation. With people thus concerned for their health and the well-being of our planetary ecology, the issues related to their concerns need to be addressed. These issues and fears of GM foods fall into three categories: Human health risks, environmental hazards, and economic concerns [4].

Health-related issues

"Several animal studies indicate serious health risks associated with GM food," including infertility, immune problems, accelerated aging, insulin regulation, and changes in major organs and the gastrointestinal system [1].

Allergens and toxins

People with food allergies have an unusual immune reaction when they are exposed to specific proteins, called allergens, in food. About 2 percent of people across all age groups have a food allergy of some sort [11]. The majority of foods do not cause any allergy in the majority of people. Food-allergic people usually react only to one or a few allergens in one or two specific foods. A major safety concern raised with regard to genetic engineering technology is the risk of introducing allergens and toxins into otherwise safe foods. The Food and Drug Administration (FDA) checks to ensure that the levels of naturally occurring allergens in foods made from transgenic organisms have not significantly increased above the natural range found in conventional foods. Transgenic technology is also being used to remove the allergens from peanuts, one of most serious causes of food allergy.

Antibiotic resistance

Antibiotic resistance genes are used to identify and trace a trait of interest that has been introduced into plant cells. This technique ensures that a gene transfer during the course of genetic modification was successful. Use of these markers has raised concerns that new antibiotic resistant strains of bacteria will emerge. The rise of diseases that are resistant to treatment with common antibiotics is a serious medical concern of some opponents of genetic engineering technology.

The potential risk of transfer from plants to bacteria is substantially less than the risk of normal transfer between bacteria, or between us and the bacteria that naturally occur within our alimentary tracts. Nevertheless, to be on the safe side, FDA has advised food developers to avoid using marker genes that encode resistance to clinically important antibiotics.

Environmental and ecological issues

Development of resistant weeds

There is a belief among some opponents of genetic engineering technology that transgenic crops might cross pollinate with related weeds, possibly resulting in "super weeds" that become more difficult to control. One concern is that pollen transfer from glyphosate-resistant crops to related weeds can confer resistance to glyphosate. Gene movement from crop to weed through pollen transfer has been demonstrated for GM crops when the crop is grown near a closely related weed species [5]. While the chance of this happening, although extremely small, is not inconceivable, resistance to a specific herbicide does not mean that the plant is resistant to other herbicides, so affected weeds could still be controlled with other products.

Some people are worried that genetic engineering could conceivably improve a plant's ability to "escape" into the wild and produce ecological imbalances or disasters. Most crop plants have significant limitations in their growth and seed dispersal habits that prevent them from surviving long without constant nurture by humans, and they are thus unlikely to thrive in the wild as weeds.

Impacts on "nontarget" species or Harm to other organisms

Another concern centering on impacts of biotechnology is possible harm of GM seeds and crops to other, beneficial organisms. Very little research exists to support this concern. Some environmentalists maintain that once transgenic crops have been released into the environment, they could have unforeseen and undesirable effects. Although transgenic crops are rigorously tested before being made commercially available, not every potential impact can be foreseen. *Bt* corn, for instance, produces a very specific pesticide intended to kill only pests that feed on the corn.

A study performed at Cornell University received significant publicity. This study indicated that a gene contained within Bt corn can be harmful to the larvae of a monarch butterfly when windblown onto milkweed leaves. But subsequent research has indicated that the actual level of Bt on milkweed plants in a real-life scenario do not reach the levels that produce a toxic results in the larvae [25]. In fact, this later research suggests that the impact of Bt corn when genetically placed in the corn is far less damaging to non-target insect populations than spraying pesticides [6]. But follow-up field studies showed that under real-life conditions Monarch butterfly caterpillars are highly unlikely to come into contact with pollen from *Bt* corn that has drifted onto milkweed leaves—or to eat enough of it to harm them.

Insecticide resistance

Another concern related to the potential impact of agricultural biotechnology on the environment involves the question of whether insect pests could develop resistance to crop-protection features of transgenic crops. There is fear that large-scale adoption of *Bt* crops will result in rapid build-up of resistance in pest populations. Insects possess a remarkable capacity to adapt to selective pressures, but to date, despite widespread planting of *Bt* crops, no *Bt* tolerance in targeted insect pests has been detected.

One particular strategy that has been developed to prevent the growth of pests resistant to GM seeds is "refuge areas." These areas are swaths of land, planted with non-GM crops, which act as refuges for the pests. Pests migrate to and remain in these areas, where they eat and breed. Since the refuge area offers the pest adequate food, the pest has no need to become resistant to GM crops, and thus the bulk of the crop is protected. The use of refuge areas is now mandated by the EPA [23].

Loss of biodiversity

Many environmentalists, including farmers, are very concerned about the loss of biodiversity in our natural environment. Increased adoption of conventionally bred crops raised similar concerns in the past century, which led to extensive efforts to collect and store seeds of as many varieties as possible of all major crops. These "heritage" collections in the USA and elsewhere are maintained and used by plant breeders. Modern biotechnology has dramatically increased our knowledge of how genes express themselves and highlighted the importance of preserving genetic material, and agricultural biotechnologists also want to make sure that we maintain the pool of genetic diversity of crop plants needed for the future. While transgenic crops help ensure a reliable supply of basic foodstuffs, U.S. markets for specialty crop varieties and locally grown produce appear to be expanding rather than diminishing. Thus the use of genetically modified crops is unlikely to negatively impact biodiversity.

Economic Concerns

Bringing a GM food to market is a lengthy and costly process. Yet consumer advocates are worried that patenting these new plant varieties will raise the price of seeds so high that small farmers and third world countries will not be able to afford seeds for GM crops, Patent enforcement may also be difficult, as the contention of the farmers that they involuntarily grew Monsanto-engineered strains. One way to combat possible patent infringement is to introduce a "suicide gene" into GM plants. These plants would be viable for only one growing season and would produce sterile seeds that do not germinate. Farmers would need to buy a fresh supply of seeds each year. However, this would be financially disastrous for farmers [16].

Limited rights to retain and reuse seed

Under a private contract between a grower and a biotech company, the grower's rights to the purchased seed are significantly limited. Such contracts generally contain a "no saved seed" provision [18]. This provision prohibits growers from saving seed and/or reusing seed from GM crops. In effect, the provision requires growers of GM crops to make an annual purchase of GM seeds.

Conclusion and future prospects

Modern biotechnology represents unique applications of science that can be used for the betterment of society through development of crops with improved nutritional quality, resistance to pests and diseases, and reduced cost of production. Genetically-modified foods have the potential to solve many of the world's hunger and malnutrition problems, and to help protect and preserve the environment by increasing yield and reducing reliance upon chemical pesticides and herbicides. Yet there are many challenges ahead for governments, especially in the areas of safety testing, regulation, international policy and food labeling. Many people feel that genetic engineering is the inevitable wave of the future and that we cannot afford to ignore a technology that has such enormous potential benefits. However, we must proceed with caution to avoid causing unintended harm to human health and the environment as a result of our enthusiasm for this powerful technology.

Perhaps the only conclusion to be drawn from a consideration of the benefits and concerns raised by GM seeds is that neither full-scale adoption nor full-scale rejection is a viable option. The technology may be more appropriate for farmers that have difficulty spraying pesticides and herbicides. GM seeds may work well for farm areas that are inaccessible to tractors or close to water bodies, or in places where winds are high. Conversely, GM seeds may be least appropriate for farmers who are particularly reliant on a stable market. The uncertainty surrounding consumer acceptance of GM products, particularly in foreign markets, is a risk that may simply be unacceptable to some farmers.
Certainly, too, the potential benefits of these genetically engineered organisms promise to be considerable. But an uneducated acceptance of this technology by farmers is not the proper response. The technology of GM seeds and the attendant legal issues raise concerns that may work against an individual farmer. The best response of every farmer is to educate him about this technology and to carefully read all legal documents before deciding to plant GM seeds.

Responsible scientists, farmers, food manufacturers, and policy makers recognize that the use of transgenic organisms should be considered very carefully to ensure that they pose no environmental and health risks or at least no more than the use of current crops and practices. Generally, Biotechnology, in the form of genetic engineering, is a facet of science that has the potential to provide important benefits if used carefully and ethically. Farmers should understand both the benefits and concerns that are raised by the use of GM organisms before they adopted the technology. Society should be provided with a balanced view of the fundamentals of biotechnology and genetic engineering, the processes used in developing transgenic organisms, the types of genetic material used, and the benefits and risks of the new technology.

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