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GENETICALLY MODIFIED CROPS: FOOD OF THE FUTURE (REVIEW)

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ABSTRACT

Since time began we humans have always relied on plants and animals to provide us with food, shelter, clothing and fuel with the population expected to reach over 10 billion by the year 2030 it is estimated that the world food production will have to double on the farmland that exists today. The ever-increasing needs of yields of crops and the decreasing crop inputs such as water and fertilizer can all be helped by biotechnology as can advancements in providing pest control that is better for our environment.
1) Bacillus Thuringiensis Brinjal is right now in the middle of a environmental and health controversy in India. This is a genetically modified strain of the non-GM Brinjal created by India's top seeds company Maharashtra Hybrid Seed Company (Mahyco) in collaboration with American multinational seed company Monsanto.
2) Bt corn is a variant of maize, genetically altered to express the bacterial Bt toxin, which was achieved by inserting a gene from the lepidoptera pathogen microorganism *Bacillus thuringiensis* into the corn genome. This gene codes for a toxin that causes the formation of pores in the larval digestive tract. This is contrary to the common misconception that Bt toxin kills the larvae by starvation.
3) Golden rice is a variety of *Oryza sativa* rice produced through genetic engineering to biosynthesize beta-carotene , a precursor of pro-vitamin A in the edible parts of rice. Golden rice was developed as a fortified food to be used in areas where there is a shortage of dietary vitamin A. The *psy* and *crt1* genes were transformed into the rice nuclear genome.

Keywords: pest control, Bacillus Thuringiensis, Brinjal, corn, Golden rice

Content:

Agricultural biotechnology

With the population expected to reach over 10 billion by the year 2030 it is estimated that the world food production will have to double on the farmland that exists today, if it is to compete with the anticipated growth in the population. The ever-increasing needs of yields of crops and the decreasing crop inputs such as water and fertilizer can all be helped by biotechnology as can advancements in providing pest control that is better for our environment.

Genetically Modified Plants

Genetically modified (GM) foods are foods derived from genetically modified organisms. Genetically modified organisms have had specific changes introduced into their DNA by genetic

engineering,

Figure 1 : Transgenic rice

using a process of either Cisgenesis or Transgenesis. These techniques are much more precise than mutagenesis (mutation breeding) where an organism is exposed to radiation or chemicals to create a non-specific but stable change. Other techniques by which humans modify food organisms include selective breeding (plant breeding and animal breeding), and somaclonal variation.

GM foods were first put on the market in the early 1990s. Typically, genetically modified foods are transgenic plant products: soybean, corn, canola, and cotton seed oil. But animal products have also been developed. In 2006 a pig was controversially [1, 2] engineered to produce omega-3 fatty acids through the expression of a roundworm gene produced. [3] Researchers have also developed a genetically-modified breed of pigs that are able to absorb plant phosphorus more efficiently, and as a consequence the phosphorus content of their manure is reduced by as much as 60%. Critics have objected to GM foods on several grounds, including perceived safety issues, ecological concerns, and economic concerns raised by the fact that these organisms are subject to intellectual property law [4].

Bacillus thuringiensis

Bacillus thuringiensis (or **Bt**) is a Gram-positive, soil-dwelling bacterium, commonly used as a pesticide. Additionally, *B. thuringiensis* also occurs naturally in the gut of caterpillars of various types of moths and butterflies, as well as on the dark surface of plants. [5]

Scientific classification

Kingdom	:	Eubacteria
Phylum	:	Firmicutes
Class	:	Bacilli
Order	:	Bacillales
Family	:	Bacillaceae
Genus	:	*Bacillus*
Species	:	*Thuringiensis*

B. thuringiensis was first discovered in 1901 by Japanese biologist Shigetane Ishiwata. In 1911 it was rediscovered in Germany by Ernst Berliner, who isolated it as the cause of a disease called Schlaffsucht in flour moth caterpillars. In 1979, Zakharyan reported the presence of a plasmid in a strain of *B. thuringiensis* and suggested its involvement in endospore and crystal formation [6, 7]. *B. thuringiensis* is closely related to *B.cereus*, a soil bacterium, and *B.anthracis*, the cause of anthrax: the three organisms differ mainly in their plasmids. Like other members of the genus, all three are aerobes capable of producing endospores.[5] Upon sporulation, *B. thuringiensis* forms crystals of proteinaceous insecticidal δ-endotoxins (called crystal proteins or Cry proteins), which are encoded by *cry* genes [8]. In most strains of *B. thuringiensis* the *cry* genes are found within the bacterias plasmid [9, 10 11].

Cry toxins have specific activities against species of the orders Lepidoptera (moths and butterflies), Diptera (flies and mosquitoes), Coleoptera (beetles), hymenoptera (wasps, bees, ants and sawflies) and nematodes. Thus, *B. thuringiensis* serves as an important reservoir of Cry toxins and *cry* genes for production of biological insecticides and insect-resistant genetically modified crops. When insects ingest toxin crystals the alkaline pH of their digestive tract causes the toxin to become activated. It becomes inserted into the insect's gut cell membranes forming a pore resulting in swelling, cell lysis and eventually killing the insect.[12, 13]

Use in pest control

Spores and crystalline insecticidal proteins produced by *B. thuringiensis* have been used to control insect pests since the 1920s [14]. They are now used as specific insecticides under trade names such as Dipel and Thuricide. Because of **their** specificity, these pesticides are

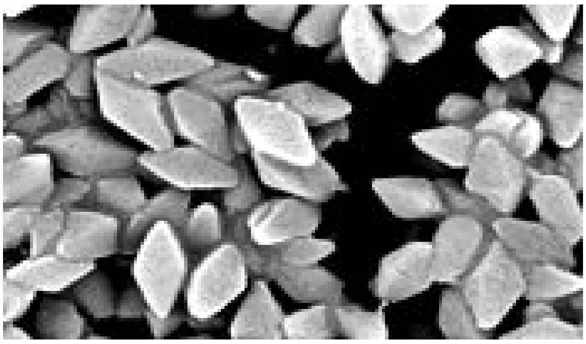

Figure 2 : Bacillus thuringiensis

regarded as environmentally friendly, with little or no effect on humans, wildlife, pollinators, and most other beneficial insects. The Belgian company Plant Genetic Systems was the first company (in 1985) to develop genetically engineered (tobacco) plants with insect tolerance by expressing *cry* genes from *B. thuringiensis* [15, 16]. *B. thurigiensis*-based insecticides are often applied as liquid sprays on crop plants, where the insecticide must be ingested to be effective. It is thought that the solubilized toxins form pores in the midgut epithelium of susceptible larvae. Recent research has suggested that the midgut bacteria of susceptible larvae are required for *B. thuringiensis* insecticidal activity [17]. *Bacillus thuringiensis* serovar israelensis, a strain of *B. thuringiensis* is widely used as a larvicide against mosquito larvae, where it is also considered an environmentally friendly method of mosquito control.

Development

The first commercially grown genetically modified whole food crop was a tomato (called FlavrSavr), which was modified to ripen without softening, by a Californian company Calgene [18]. Calgene took the initiative to obtain FDA approval for its release in 1994 without any special labeling, although legally no such approval was required [19]. It was welcomed by consumers who purchased the fruit at a substantial premium over the price of regular tomatoes. However, production problems and competition from a conventionally bred, longer shelf-life variety prevented the product from becoming profitable. A variant of the Flavr Savr was used by Zeneca to produce tomato paste which was sold in Europe during the summer of 1996 [20]. The labeling and pricing were designed as a marketing experiment, which proved, at the time, that European consumers would accept genetically engineered foods.Currently, there are a number of food species in which a genetically modified version exists.

Food	Properties of the genetically modified variety	Modification
Soybeans	Resistant to glyphosate or glufosinate herbicides	Herbicide resistant gene taken from bacteria inserted into soybean
Corn, field	Resistant to glyphosate or glufosinate herbicides, Insect resistance - using Bt proteins some previously used as pesticides in organic crop production. .	New genes added/transferred into plant genome. Vitamin-enriched corn derived from South African white corn variety M37W has bright orange kernels, with 169x increase in beta carotene, 6x the vitamin C and 2x folate.(Shaista Naqvi, et al)
Cotton (cottonseed oil)	Pest-resistant cotton	Bt crystal protein gene added/transferred into plant genome
Hawaiian papaya	Variety is resistant to the papaya ringspot virus.(Richard M. Manshardt)	New gene added/transferred into plant genome
Tomatoes	Variety in which the production of the	A reverse copy (an antisense gene) of the gene

	enzyme polygalacturonase (PG) is suppressed, retarding fruit softening after harvesting.(FDA Backgrounder: May 18, 1994)	responsible for the production of PG enzyme added into plant genome
Potatoes	*Amflora* variety produces waxy potato starch composed almost exclusively of the amylopectin component of starch.[11]	The gene for granule bound starch synthase (GBSS) (the key enzyme for the synthesis of amylose) was switched off by inserting antisense copy of the GBSS gene.
Rapeseed (Canola)	Resistance to herbicides (glyphosate or glufosinate), high laurate canola[12]	New genes added/transferred into plant genome
Sugar cane	Resistance to certain pesticides, high-sucrose cane.	New genes added/transferred into plant genome
Sugar beet	Resistance to glyphosate, glufosinate herbicides	New genes added/transferred into plant genome
Sweet corn	Produces its own bioinsecticide (Bt toxin)	Gene from the bacterium Bacillus thuringiensis added to the plant.
Rice	Genetically modified to contain high amounts of Vitamin A (beta-carotene)	"Golden rice" Three new genes implanted: two from daffodils and the third from a bacterium

Table.1: food species & Modification

1) Bacillus Thuringiensis Brinjal

Bacillus Thuringiensis Brinjal**,** popularly known as Bt brinjal, is right now in the middle of a environmental and health controversy in India. This is a genetically modified strain of the non-GM Brinjal created by India's top seeds company Maharashtra Hybrid Seed Company (Mahyco) in collaboration with American multinational Monsanto and stakes a claim to improve the yields many fold and also help the agricultural sector claims to improve yields and help the agriculture sector. Researchers, environmentalists, scientists and Environmental Organizations like Greenpeace have for the last year been trying to stop the manufacture of this **"**ninja brinjal**."**

Following the mass farmer suicides over the failure of the BT cotton crop many states have been against the use and production of this Brinjal. But the Centre was still adamant on going ahead with manufacture, as it would accelerate yield and will shorten growth time of the crop. Union Environmental Minister, Jairam Ramesh has finally relented and said, said there was 'no over-riding urgency to introduce Bt Brinjal in India'.

Figure 3 : *Bacillus thuringiensis* Brinjal

Figure 4 : Golden rice

Golden rice is a variety of *Oryza sativa* rice produced through genetic engineering to biosynthesize beta-carotene, a precursor of pro-vitamin A in the edible parts of rice. The scientific details of the rice were first published in *Science* in 2000 [21]. Golden rice was developed as a fortified food to be used in areas where there is a shortage of dietary vitamin A [22]. In 2005 a new variety called *Golden Rice 2* was announced which produces up to 23 times more beta-carotene than the original variety of golden rice [23]. Neither variety is currently available for human consumption. Although golden rice was developed as a humanitarian tool, it has met with significant opposition from environmental and anti-globalization activists [24].

Creation of Golden Rice:

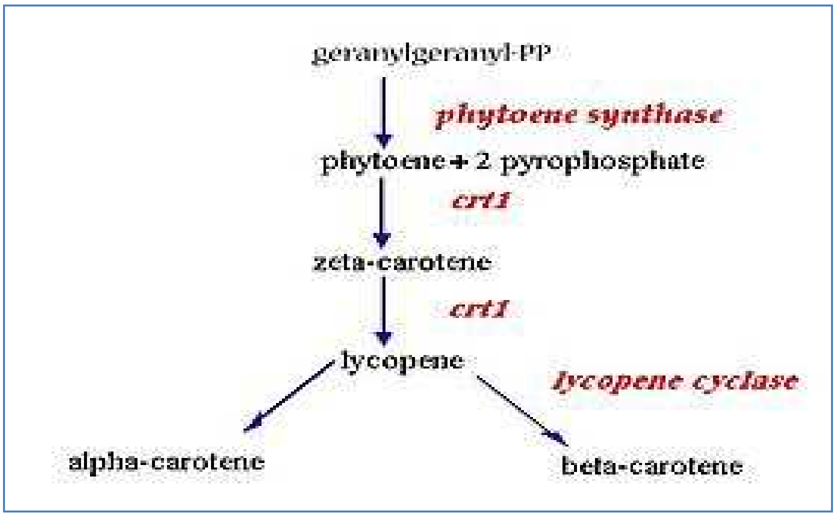

Figure 5 : Creation of golden rice

A simplified overview of the carotenoid biosynthesis pathway in golden rice. The enzymes expressed in the endosperm of golden rice, shown in red, catalyze the biosynthesis of beta-carotene from geranylgeranyl diphosphate. Beta-carotene is assumed to be converted to retinal and subsequently retinol (vitamin A) in the animal gut.

Golden rice was created by Ingo Potrykus of the Institute of Plant Sciences at the Swiss Federal Institute of Technology, working with Peter Beyer of the University of Freiburg. The project started in 1992 and at the time of publication in 2000, golden rice was considered a significant breakthrough in biotechnology as the researchers had engineered an entire biosynthetic pathway.

Golden rice was designed to produce beta-carotene, a precursor of Vitamin A, in the part of rice that people eat, the endosperm. The rice plant can naturally produce beta-carotene, which is a carotenoid pigment that occurs in the leaves and is involved in photosynthesis. However, the plant does not normally produce the pigment in the endosperm since photosynthesis does not occur in the endosperm.

Golden rice was created by transforming rice with two beta-carotene biosynthesis genes:

1. *psy* (phytoene synthase) from daffodil (*Narcissus pseudonarcissus*)
2. *crt1* from the soil bacterium *Erwinia uredovora*

(The insertion of a *lyc* (lycopene cyclase) gene was thought to be needed but further research showed that it is already being produced in wild-type rice endosperm.)

The *psy* and *crt1* genes were transformed into the rice nuclear genome and placed under the control of an endosperm specific promoter, so that they are only expressed in the endosperm. The exogenous *lyc* gene has a transit peptide sequence attached so that it is targeted to the plastid, where geranylgeranyl diphosphate formation occurs. The bacterial *crt1* gene was an important inclusion to complete the pathway, since it can catalyze multiple steps in the synthesis of carotenoids, while these steps require more than one enzyme in plants [25]. The end product of the engineered pathway is lycopene, but if the plant accumulated lycopene the rice would be red. Recent analysis has shown that the plant's endogenous enzymes process the lycopene to beta-carotene in the endosperm, giving the rice the distinctive yellow colour for which it is named [26]. The original Golden rice was called SGR1, and under greenhouse conditions it produced 1.6 µg/g of carotenoids.

3)Bt Corn

The European corn borer, *Ostrinia nubilalis*, destroys corn crops by burrowing into the stem, causing the plant to fall over.Bt corn is a variant of maize, genetically altered to express the

Figure 6 : Bt corn

bacterial Bt toxin, which is poisonous to insect pests. In the case of corn, the pest is the European Corn Borer.Expressing the toxin was achieved by inserting a gene from the lepidoptera pathogen microorganism *Bacillus thuringiensis* into the corn genome. This gene codes for a toxin that causes the formation of pores in the larval digestive tract. These pores allow naturally occurring enteric bacteria such as *E. coli* and *Enterobacter* to enter the hemocoel where they multiply and cause sepsis. This is contrary to the common misconception that Bt toxin kills the larvae by starvation.In 2001, Bt176 varieties were voluntarily withdrawn from the list of approved varieties by the United States Environmental Protection Agency (EPA) when it was found to have little or no Bt expression in the ears and was not found to be effective against second generation corn borers.

Effects of Bt corn on nontarget insects

Monarch populations in the USA during 1999 increased by 30%, despite Bt corn accounting for 30% of all corn grown in the USA that year. The beneficial effects of Bt corn on Monarch populations can be attributed to reduced pesticide use. Numerous scientific studies continue to investigate the potential effects of Bt corn on a variety of nontarget invertebrates. A synthesis of data from many such field studies found that the measured effect depends on the standard of comparison. The overall abundance of nontarget invertebrates in Cry1Ab variety Bt corn fields is significantly higher compared to non-GM corn fields treated with insecticides, but significantly lower compared to insecticide-free non-GM corn fields. Abundance in fields of another variety, Cry3Bb corn, is not significantly different compared to non-GM corn fields either with or without insecticides.

Preventing Bt resistance in pests

By law, farmers in the United States who plant Bt corn must plant non-Bt corn nearby. These non-modified fields are to provide a location to harbor pests. The theory behind these refuges is to slow the evolution of the pests to the Bt pesticide. Doing so enables an area of the landscape where wild type pests will not be immediately killed.

It is anticipated that resistance to Bt will evolve in the form of a recessive allele in the pest. Because of this, a pest that gains resistance will have an incredibly higher fitness than the wild type pest in the Bt corn fields. If the resistant pest is feeding in the non-Bt corn nearby, the resistance is neutral and offers no advantage to the pest over any non resistant pest. Ensuring that there are at least some breeding pests nearby that are not resistant, increases the chance that resistant pests will choose to mate with a nonresistant one. Since the gene is recessive, all offspring will be heterozygous, and the offspring from that mating will not be resistant to Bt and therefore no longer a threat. Using this method scientists and farmers hope to keep the number of resistant genes very low, and utilize genetic drift to ensure that any resistance that does emerge does not spread.

METHOD

Genetic modification involves the insertion or deletion of genes. In the process of Cisgenesis genes are artificially transferred between organisms that could be conventionally bred. In the process of Transgenesis genes from a different species are inserted, which is a form of horizontal gene transfer. In nature this can occur when exogenous DNA penetrates the cell membrane for any reason. To do this artificially may require attaching the genes to a virus or just physically inserting the extra DNA into the nucleus of the intended host with a very small syringe, or with very small particles fired from a gene gun. However, other methods exploit natural forms of gene transfer, such as the ability of *Agrobacterium* to transfer genetic material to plants, and the ability of *lentiviruses* to transfer genes to animal cells.

Disadvantages of Genetically Modified Foods

There are several risks of these foods. They are:

- Genetically modified foods may gain undesirable properties.
- The preservation of genetic variety in one species is difficult. The technology make farmer to produce only one type fertile plants.
- The technology may cause undesirable degeneration. So, surprisingly, low quality products may be obtained.
- Genetically modified foods may change the microbial flora of the soil. It may cause deperdition of essential microorganisms on soil. This ruin natural balance.
- When genetically altered microorganisms are consumed with food products, they may consolidate with human or animal organism. His combination may cause deperdition, metamorphosis, or any other strange organisms.
- If the foods which were made antibiotic resistant by gene technology are consumed, it may give the same property to human. This cause failure of antibiotic-based treatments.
- By this technology transferred genes may contaminate to other organisms undesirably. This may cause biologic disaster.
- As a ring of nature chain, insects may be influenced by genetically modified foods and insects can develop resistant mechanism.
- Even beneficial foods that carry toxic effect genes can cause human illness.
- There is a risk of formation one kind of flora.
- Other organisms in the same medium may be influenced by genetically modified foods.

A**dvantages of GM foods**

The world population has topped 6 billion people and is predicted to double in the next 50 years. Ensuring an adequate food supply for this 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:

1) Pest resistance Crop losses from insect pests can be staggering, resulting in devastating financial loss for farmers and starvation in developing countries. 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 Bt. corn can help eliminate the application of chemical pesticides and reduce the cost of bringing a crop to market [27, 28].

2) Herbicide tolerance

Crop plants genetically-engineered to be resistant to one very powerful herbicide could help 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 ®.(Roundup Ready ? Soybeans)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 [29].

3) Dsease resistance There are many viruses, fungi and bacteria that cause plant diseases. Plant biologists are working to create plants with genetically-engineered resistance to these diseases [30, 31]

4) Cold tolerance Unexpected frost can destroy sensitive seedlings. An antifreeze gene from cold water fish has been introduced into plants such as tobacco and potato. With this antifreeze gene, these plants are able to tolerate cold temperatures that normally would kill unmodified seedlings [32]. (Note: I have not been able to find any journal articles or patents that involve fish antifreeze proteins in strawberries, although I have seen such reports in newspapers. I can only conclude that nothing on this application has yet been published or patented.)

5) Drought tolerance/salinity tolerance As the world population grows and more land is utilized for housing instead of food production, farmers will need to grow crops in locations previously unsuited for plant cultivation. Creating plants that can withstand long periods of drought or high salt content in soil and groundwater will help people to grow crops in formerly inhospitable places [33, 34]

6) Nutrition Malnutrition is common in third world countries where impoverished peoples rely on a single crop such as rice for the main staple of their diet. However, rice does not contain adequate amounts of all necessary nutrients to prevent malnutrition. If rice could be genetically engineered to contain additional vitamins and minerals, nutrient deficiencies could be alleviated. For example, blindness due to vitamin A deficiency is a common problem in third world countries. 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). (Swiss Federal Institute of Technology Institute for Plant Sciences)Since this rice was funded by the Rockefeller Foundation, (Rockefeller Foundation) a non-profit organization, the Institute hopes to offer the golden rice seed free to any third world country that requests it. Plans were underway to develop golden rice that also has increased iron content. However, the grant that funded the creation of these two rice strains was not renewed, perhaps because of the vigorous anti-GM food protesting in Europe, and so this nutritionally-enhanced rice may not come to market at all [35].

7) Pharmaceuticals Medicines and vaccines often are costly to produce and sometimes require special storage conditions not readily available in third world countries. Researchers are working to develop edible vaccines in tomatoes and potatoes [36, 37]. These vaccines will be much easier to ship, store and administer than traditional injectable vaccines.

8) Phytoremediation Not all GM plants are grown as crops. Soil and groundwater pollution continues to be a problem in all parts of the world. Plants such as poplar trees have been genetically engineered to clean up heavy metal pollution from contaminated soil [38].

CONCLUSION

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.

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