Antibiotic resistant tobacco was the first GM crop plant in the world developed in 1983. In 1992, China was the first country to approve commercialization of transgenic tobacco resistant to cucumber mosaic virus. In 1994, the US also approved the first GM tomato “flavr Savr” for commercialization. After this a number of GM crops like glyphosate resistant soybean, Bt cotton, Bt maize, virus resistant squash, etc. have been approved for commercialization in different countries.

The area under GM crops in the world is increasing every year and in 2014 it occupied 181.5 million hectares in the world. GM technology holds promise to solve some of the basic problems related to agriculture. Therefore, a rational, scientific and evidence-based evaluation of this technology is essential.

Since the beginning of crop domestication, people have felt the need for improving crop plants to increase productivity and enhance the quality of food grain to satisfy the human needs. Traditionally, various plant breeding methods were used by plant breeders for increasing crop production. These conventional plant breeding methods were very successful and helped to meet the demand of the growing population.

Another strategy for crop improvement is the transfer of one or more desired genes from sexually compatible or incompatible species or the selective modification of DNA sequences using recombinant DNA (rDNA) technology. Crops developed using rDNA technologies are called genetically modified crops (GM crops) or transgenic crops.
GM technology holds promise to solve some of the basic problems related to agriculture. Therefore, a rational, scientific and evidence-based evaluation of this technology is essential.

Brinjal (Egg plant) is one of the main vegetables in India. The major problem in brinjal is the infestation by fruit and shoot borer \( (Leucinodes orbonalis) \). The larvae feed inside the fruit, due to which the fruit is not suitable for human consumption. A single larva can damage 4-6 fruits. Sometime excess infestation results in total failure of the crop.

For the control of brinjal fruit and shoot borer, farmers are using excess of pesticides which is harmful for the environment and human health. Maharashtra-based seed company Mahyco has developed Bt Brinjal that contains Cry1Ac gene from Bt bacteria, which renders the brinjal crop resistant to fruit and shoot borer. The GEAC (Genetic Engineering Appraisal Committee) which permits the commercialization of GM crops in India approved Bt brinjal for commercialization in 2009.

However, soon after the approval several scientists, farmers and some Non Government Organizations (NGOs) raised certain questions about its biosafety which delayed its release. Therefore, in February 2010, the environment ministry issued a moratorium on the release of Bt Brinjal in India. However, Bangladesh approved Bt Brinjal for seed production and initial commercialization on 30 October 2013. In the next coming years Bangladesh is planning to increase the area under Bt brinjal (Source ISAAA).

Now, what are some environmental, economical and health related issues due to which some scientists, NGO and others are criticising this GM technology? Let’s take a look.

ENVIRONMENTAL ISSUES

Biodiversity: Biodiversity refers to the diversity in all forms of life present in earth. It can be genetic, species or ecosystem diversity. Humans have dominated the planet and changed the planet according to their needs which has resulted in the loss of biodiversity.

Agriculture, industrialization, loss of forest, loss of habitats, and climate change are some of the main reasons for this loss of biodiversity. Agriculture practise like ploughing, tilling, monoculture, use of herbicides, pesticides and insecticides results in loss of beneficial insects, plants and other forms of life that ultimately results in loss of biodiversity. Loss of biodiversity is a general problem associated with present-day agriculture.

In 1999, a paper was published in the Nature magazine which reported the detrimental effect of Bt maize on Monarch butterfly, which is an endangered species of butterfly found in North America. When the butterfly larvae were fed on milkweed leaves (Monarch butterfly larvae feed only on milkweed leaves) covered in Bt maize pollen, it failed to grow. This led to concerns that Bt crops could give rise to major environmental problems. Later, a different group of scientists analyzed the Bt pollen toxicity to monarch butterfly. They found that one of the events Bt176 which contains a pollen specific promoter had high level of cry protein expression (1.1-7.1 microgram per gm) leading to the toxic effects observed on the butterfly larvae. So, Bt176 event has now been removed from the market.

In 2011, a review was published on “Impact of GM crops on Biodiversity” (Janet E. Carpenter, 2011, GM Crops, 2:1, 7-23). In this review, it was concluded that GM crops had reduced the impact of agriculture on biodiversity. Cultivation of insect-resistant GM crops reduces the application of insecticides and pesticides and thus prevents the killing of beneficial insect population. Similarly, herbicide-resistant crops result in less tillage and preservation of soil moisture.

Gene flow and cross pollination: Gene flow refers to the transfer of gene or genetic material from one plant species to other plant species. It is a natural process that may lead to evolution of new species. Gene flow can occur in two ways either from the crop to its wild relative or from crop to weed plant. Gene flow can
result in contamination of wild relatives of crop plant which results in reduction of germplasm or transfer of novel trait into the weed plant (can give rise to superweeds). Serious consequences can occur, so avoiding gene flow in case of transgenics is necessary for which various strategies have been proposed (Table 1).

**Superweeds:** Superweed is a plant that is resistant to some dose of herbicides. Superweed may arise due to continuous use of single herbicide or gene flow from transgenic to weed species. It is true that herbicide-tolerant GM crops have given rise to superweeds but the superweed also occurs in conventional agriculture. Even before commercialization of GM crops there were certain weeds that were resistant to herbicides. There are around 24 glyphosate-resistant weeds that emerged after the release of glyphosate-resistant crops, but there were around 64 atrazine-resistant weeds even before the development of atrazine-resistant crops (Table 2).

Superweed is not a new problem that came as a result of the introduction of GM crops. However, they can be destroyed by different types of herbicides and by different crop management practices.

**ECONOMICS ISSUES**

Multinational companies in agriculture sector: Development of GM crops involves various steps like gene isolation, cloning to plant transformation, regeneration, phenotypic and molecular analysis, multilocation field trials and analysis of various biosafety parameters, etc. It involves a large amount of money, that’s why most of the transgenic crops are developed by multinational companies (MNCs). MNCs existed in agriculture even before the advent of GM technology. Most of the herbicides, insecticides, pesticides and seed companies are multinational. Hence, the argument that GM crops will let in multinational companies in agriculture is not appropriate.

Seed purchase and cost: Farmers usually store some parts of seeds after harvest and use it the next year. Terminator seed technology can develop seeds that will not germinate in the subsequent year so farmers have to purchase new seeds every year. But this technology is not approved for use. There are no terminator seeds of any crop available in the market. Although in case of hybrids farmers have to purchase new seeds every year whether that hybrid is GM or not. However, GM seeds are costly as compared to their conventional non-GM counterpart.

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>No. of resistant weeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atrazine</td>
<td>64</td>
</tr>
<tr>
<td>Imazethapyr</td>
<td>39</td>
</tr>
<tr>
<td>Tribenuron-methyl</td>
<td>35</td>
</tr>
<tr>
<td>Imazamox</td>
<td>32</td>
</tr>
<tr>
<td>Chlorsulfuron</td>
<td>31</td>
</tr>
<tr>
<td>Simazine</td>
<td>31</td>
</tr>
<tr>
<td>Paraquat</td>
<td>26</td>
</tr>
<tr>
<td>Glyphosate</td>
<td>24</td>
</tr>
</tbody>
</table>

**TABLE 1:** Different strategies for avoiding gene flow

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Principle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloroplast transformation</td>
<td>Expressed gene in chloroplast which is maternally inherited</td>
</tr>
<tr>
<td>Male sterility</td>
<td>No pollen production</td>
</tr>
<tr>
<td>Terminator technology</td>
<td>Seeds are sterile</td>
</tr>
<tr>
<td>Spatial isolation</td>
<td>Physical barrier (tall crop, hedge, tree) between GM and non GM crop usually at the boundary of the crop</td>
</tr>
<tr>
<td>GM crop-free zone</td>
<td>Select some region where wild relatives dominate and declare that region as GM-free region</td>
</tr>
</tbody>
</table>

Star link is a maize variety which was released for animal feed. It was not released for human consumption because it contains cry 9C gene which is stable at acidic pH.

There are some projects of GM crops that have a humanitarian aim. Golden rice is one of the examples. The development of Golden rice involves 70 different Intellectual Property Rights (IPR). A free licence has been granted for the Golden rice on humanitarian grounds by the IPR holders.
Farmer’s profit: There is a continuous debate among different groups worldwide that GM crops reap benefits for MNCs only, while some groups consider that the farmers are benefitted as well.

Jonas Kathage and Matin Qaim have studied the economic impact of Bt cotton in India. They carried out an analysis on 533 small household farmers involved in cultivation of Bt cotton with an average cotton area of 3-4 acre in the states of Maharashtra, Karnataka, A.P. and Tamil Nadu taking different parameters like seed cost, costs on spraying chemical pesticides, yield and overall income. Their results showed that the cotton yield has increased by 24% and the profits of farmers have gone up by 50%. Although Bt cotton seeds were costly than their conventional counterpart, the farmers income increases due to higher yield and reduced application of pesticides.

HEALTH ISSUES

The public concern about GM crops is the safety of GM food. Today, consumers are interested in knowing about the source of foods they consume. So, the question about the safety of GM food is obvious.

Before the release of any GM food, it is evaluated for various biosafety parameters and then only it can be released for human consumption. It has never happened in the past that such evaluation has taken place before the release of any crop for human consumption.

Another concern is about eating genes and DNA in food from GM sources. All foods contain genes and DNA that get digested and disposed off in the usual way. Humans have been consuming genes since evolution but there is no report that genes can enter human cells from food.

Despite the fact that GM food is carefully assessed, various controversies happened in past regarding safety of GM food. In the 1990s, Dr. Arpad Pusztai claimed that rat fed on GM potato had severe immune system damage and stunted growth. However, it was not made clear that the research was experimental and the potatoes were not being developed as food crop. Later, a number of studies have been published which showed that experimental design, technique and data was insufficient to draw any conclusion from it.

Starlink is a maize variety which was released for animal feed. It was not released for human consumption because it contains cry 9C gene which is stable at acidic pH. In 2000, contamination of Starlink maize in human food was observed. Therefore, it was removed from the market. Another example dates to 2004 when a large number of people in a village of Philippines showed allergic reaction that caused a range of symptoms. Again a controversy was created that this allergic reaction was due to Bt corn.

Therefore, to settle concerns about the safety of GM food several questions need to be answered, such as, how the safety of GM crops should be measured, what are the features that are to be tested, what kind of analysis is required, what are the parameters of biosafety that need to be tested, and so on.

GM technology holds promise to solve some of the basic problems related to agriculture. Therefore, a rational, scientific and evidence-based evaluation of this technology is essential.

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TOP TEN GENETICALLY MODIFIED FOODS

- Corn
- Soy
- Cottonseed
- Papaya
- Rice
- Rapeseed (Canola)
- Potatoes
- Tomatoes
- Dairy products
- Peas

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