

Genetically modified crops in India

- *The current status of GM crops in India*

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Agenda

1. What is Genetic modification?
2. Issues related Genetic modification.
3. How India fits in the picture of GM Crops?
4. Future of GM crops in India and the world.

What is Genetic Modification?

Genetic modification involves altering an organism's DNA. This can be done by altering an existing section of DNA, or by adding a new gene altogether.

A gene is a code that governs how we appear and what characteristics we have.

Like animals, plants have genes too. Genes decide the colour of flowers, and how tall a plant can grow. Like people, the characteristics of a plant will be transferred to its children- the plant seeds, which grow into new plants.

When a scientist genetically modifies a plant, they insert a foreign gene in the plant's own genes. This might be a gene from a bacterium resistant to pesticide, for example. The result is that the plant receives the characteristics held within the genetic code. Consequently, the genetically modified plant also becomes able to withstand pesticides.

Not only genetic modification can be used to change animal and plant genes. Spontaneous changes, radiation, chemicals and traditional processing can also alter the characteristics of a plant or animal.

Spontaneous alteration of genes takes place naturally and sometimes with no effect. A spontaneous alteration can lead to the development of both positive and negative characteristics. The method is not particularly good if the intention is to create specific changes.

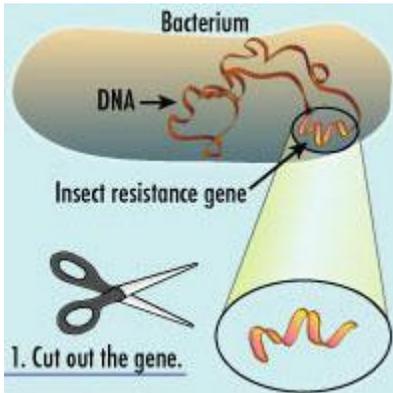
Radiation and chemicals can be used in order to effect gene alteration. Both elements are sometimes used in plant processing.

With genetic modification it is possible to transfer genes from one species to another. This is because all genes, be they human, plant, animal or bacterial are created from the same material. Genetic scientists therefore have a huge amount of genetic characteristics to choose from.

How does a genetic scientist work?

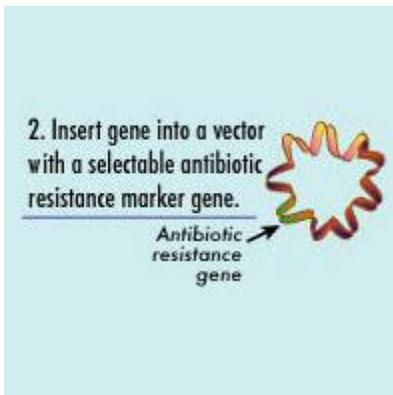
Genetic modification of plants occurs in several stages:

1. An organism that has the desired characteristic is identified.
2. The specific gene that produces this characteristic is located and cut out of the plant's DNA.

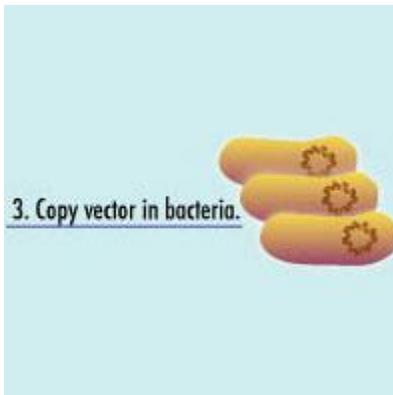


3. To get the gene into the cells of the plant being modified, the gene needs to be attached to a carrier. A piece of bacterial DNA called a plasmid is joined to the gene to act as the carrier.

4. A type of switch, called a 'promoter', is also included with the combined gene and carrier. This helps make sure the gene works properly when it is put into the plant being modified. Only a small number of cells in the plant being modified will actually take up the new gene. To find out which ones have done so, the carrier package often also includes a marker gene to identify them.

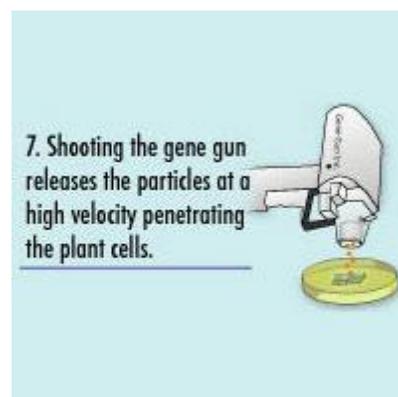
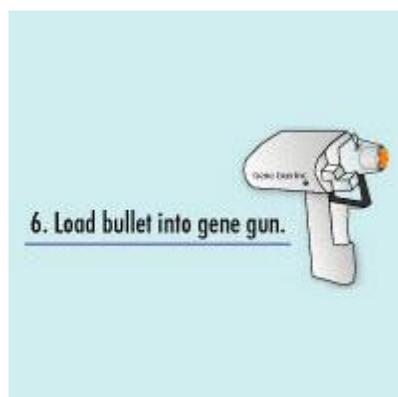
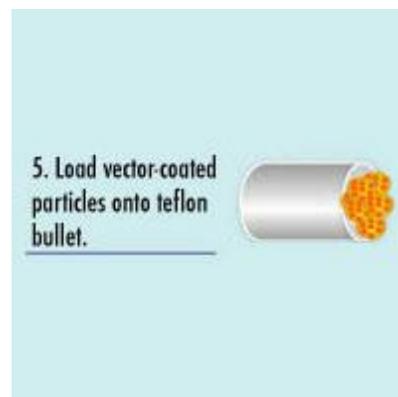
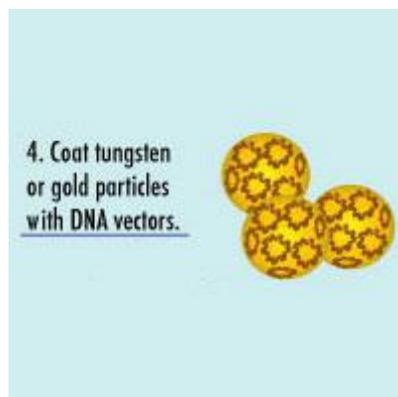


5. The gene package is then inserted back into the bacterium, which is allowed to reproduce to create many copies of the gene package.



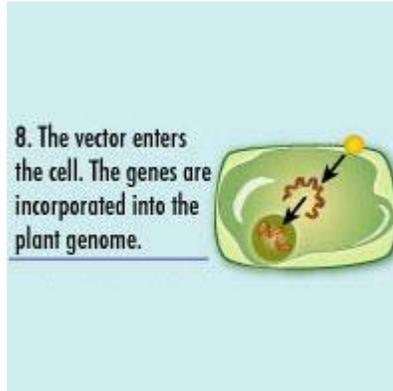
6. The gene packages are then transferred into the plant being modified. This is usually done in one of two ways:

- By attaching the gene packages to tiny particles of gold or tungsten and firing them at high speed into the plant tissue. Gold or tungsten are used because they are chemically inert – in other words, they won't react with their surroundings

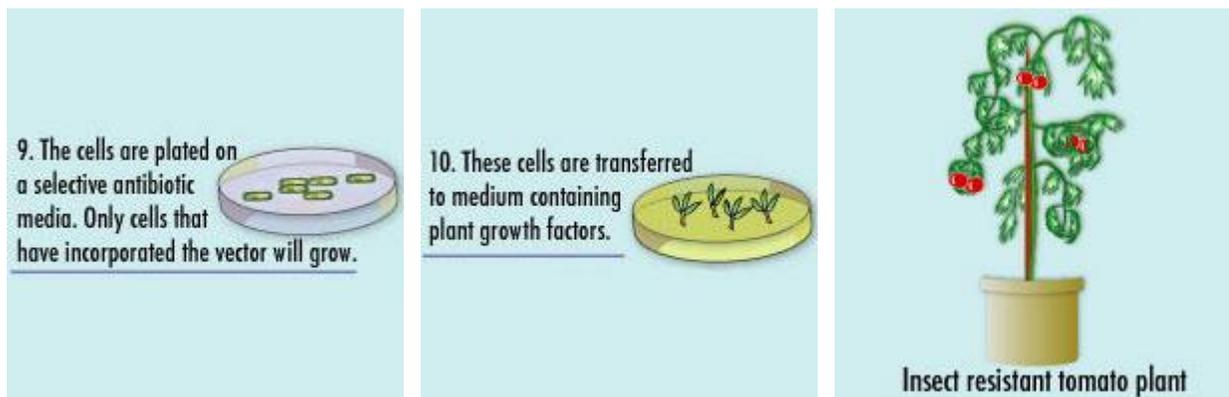


- By using a soil bacterium, called *Agrobacterium tumefaciens*, to take it in when it infects the plant tissue.

- The gene packages are put into *A. tumefaciens*, which is modified to make sure it doesn't become active when it is taken into the new plant.



7. The plant tissue that has taken up the genes is then grown into full size GM plants.



8. The GM plants are checked extensively to make sure that the new genes are in them and working, as they should. This is done by growing the whole plants, allowing them to turn to seed, planting the seeds and growing the plant again, while monitoring the gene that has been inserted. This is repeated several times.

How do we know if the genetic modification has succeeded?

Only rarely can one see whether a plant or animal has been genetically modified, with the naked eye. Scientists have therefore developed some techniques to assist them.

For example - a special colour test can identify whether a plant is genetically modified. At the time when the plant is genetically modified, the scientist inserts an extra marker gene into the plant. The marker gene can have different characteristics, for example, it can make the plant change colour when exposed to a chemical test.

In this way, scientists can identify whether the plant has been genetically modified or not by performing a chemical test and noting the colour of the plant.

Altering genes

Genetic modification does not always involve moving a gene from one organism to another. Sometimes it means changing how a gene works by 'switching it off' to stop something happening. For example, the gene for softening a fruit could be switched off so that although the fruit ripens in the normal way, it will not soften as quickly. This can be useful because it means that damage is minimized during packing and transportation.

Controlling this gene 'switch' may also allow researchers to switch on modified genes in particular parts of a plant, such as the leaves or roots. For example, the genes that give a plant resistance to a pest might only be switched on in the bit of the plant that comes under attack, and not in the part used for food.

FOR EXAMPLE:

In 2002, researchers at Cornell University in New York used a different scientific approach to develop hardier biotech rice that can resist drought and thrive in marginal soil.

In the Cornell study, researchers took the genes that synthesize trehalose - a simple sugar that is produced in a wide variety of plants, including the resurrection plant - and inserted them into rice. The resurrection plant is a desert moss that can slow its activity to zero during a drought and completely revive with the return of water.

But the University of California-Riverside method differs in that no foreign genes were introduced into the tobacco plants to make them drought resistant. Instead, Gallie's research team was able to use the tobacco plant's own genes to reduce the level of the enzyme dehydroascorbate reductase (DHAR), which reduces a plant's ability to recycle vitamin C. And that, in turn, signals the plant to slow the loss of water from its leaves.

"This reduction in vitamin C recycling causes plants to be highly responsive to dry growth conditions by reducing the rate of water that escapes from their leaves," said Gallie. "Thus, they are better able to grow with less water and survive a drought."

Here's how it works:

Plant leaves have tiny pores called stomata that open - usually in the morning when it's cooler - to allow plants to breathe in carbon dioxide, which they need to grow. In the afternoon, when it's hotter, the stomata close to conserve water. The stomata are controlled by guard cells that open and close the tiny pores based on the level of oxidizers such as hydrogen peroxide, whose level increases when exposed to environmental stresses such as drought. When oxidizer levels rise, the pores close.

An antioxidant such as vitamin C destroys these oxidizers in plants. By reducing the vitamin C levels, oxidizers remain high enough to keep the stomata closed. The plant is essentially tricked so it preserves water.

Biotechnology is an evolution of traditional agricultural methods. Over the past 10,000 years, people have routinely used their knowledge of plants to improve food production. Biotechnology is the latest development in the evolution of agricultural methods. Farmers used to rely on plant breeding to add or eliminate specific genetic traits in a plant. Those with desirable characteristics are selected over several generations. The crops and livestock we see today are a result of traditional processing. For example, because of plant breeding, corn today looks nothing like it did one hundred years ago. Although it typically took several growing seasons to produce a plant that expressed a desired trait, farmers were eventually able to produce crops that:

- Were resistant to drought, insect pests or diseases
- Possessed stronger stalks to withstand strong winds
- Produced higher yields

Genetic modification is a more efficient and precise way to achieve the benefits of crop improvement. Using new technologies, scientists are now able to pinpoint the specific gene responsible for a particular trait and then extract or add that gene to a specific plant.

Genetic modification is a more precise technique, where one can be exact in transferring the desired characteristics. In traditional processing one cannot avoid the possibility that other characteristics may also be transferred.

Genetic modification is less time-consuming than traditional processing.

In traditional processing, characteristics can only be exchanged between species which are the same or very similar. It might be maize and navew or a horse and a donkey.

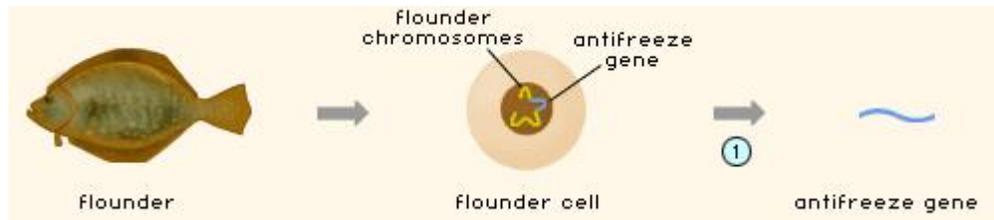
In genetic modification, it's possible to transfer genes from one species to another from plant to plant, from animal to plant, from plant to animal or from animal to animal. This is because all genes, no matter where they come from, are made of the same material - **DNA**.

FOR EXAMPLE:

How to add a fish gene to a tomato

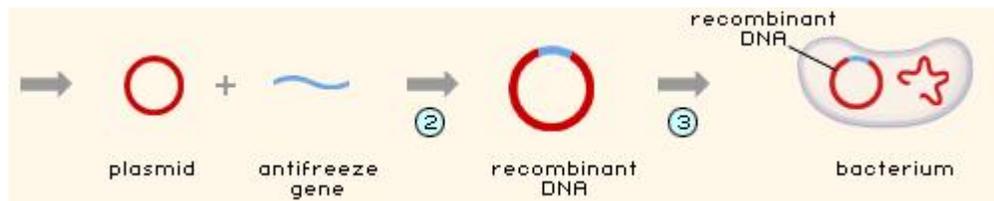
Scientists have created a frost-resistant tomato plant by adding an antifreeze gene from a cold-water fish to it. The antifreeze gene comes from the cold-water flounder, a fish that can survive in very cold conditions. This is how it was done.

- 1 The flounder has a gene to make an antifreeze chemical. This is removed from the chromosomes within a flounder cell.



- 2 The antifreeze DNA is joined onto a piece of DNA called a plasmid. This hybrid DNA, which is a combination of DNA from 2 different sources, is known as recombinant DNA.

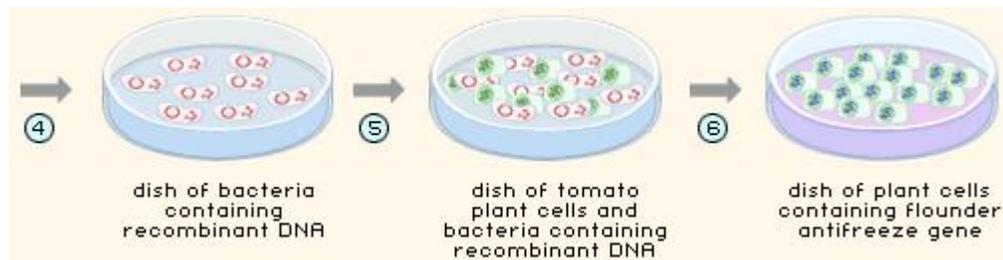
- 3 The recombinant DNA, including the antifreeze gene, is placed in a bacterium.



- 4 The bacterium is allowed to reproduce many times producing lots of copies of the recombinant DNA.

- 5 Tomato plant cells are infected with the bacteria. As a result, the antifreeze gene in the plasmid, in the bacteria becomes integrated into the tomato plant cell DNA.

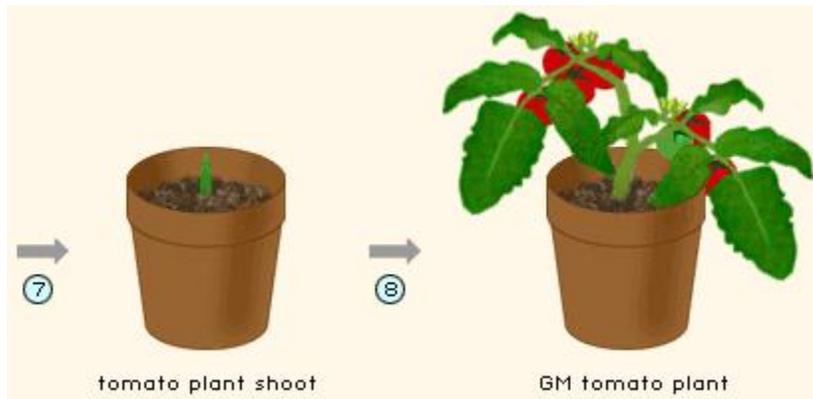
- 6 Tomato cells are placed in a growth medium that encourages the cells to grow into plants.



- 7 Tomato plant seedling is planted.

8

This GM tomato plant contains a copy of the flounder antifreeze gene in every one of its cells. The plant is tested to see if the fish gene still works. Is it frost resistant? Yes it is.



Issues related to Genetic modification

Some myths related to foods produced using biotechnology:

MYTH: Foods produced using biotechnology has not been established as safe and are not adequately regulated.

FACT: Biotechnology is one of the most extensively researched and reviewed agricultural developments in our history. The World Health Organization, the US Food and Drug Administration (FDA), the US Department of Agriculture (USDA) and the Environmental Protection Agency (EPA) have all certified the safety of these foods and work together to ensure that crops produced through biotechnology are safe to eat. Governments around the world including Canada, Australia, Singapore, Europe and Japan have reached agreement on the safety of these foods.

MYTH: Crops produced using biotechnology will negatively impact the environment.

FACT: Biotechnology is an element in sustainable agriculture that will benefit the environment. Benefits include reduced pesticide use, water and soil conservation and greater safety for workers and the ecosystem.

Many crops - including tomatoes, corn, potatoes and cotton - now have the internal ability to repel insects. Consequently, fewer applications of insecticide need to be applied to the plant. A certain type of corn used to feed hogs will reduce the phytic acid in animal waste that traditionally causes algae to grow in water supplies. Finally, the ability to obtain greater crop yield from existing land decreases the need to convert forests to farmland.

MYTH: The production of crops resistant to certain pests and weeds will lead to "Superbugs" and/or "Superweeds" that are immune to existing methods of pest and weed management.

FACT: There are no scientific studies suggesting this kind of scenario could occur as a result of crops produced using biotechnology. There are, however, many systems in place including crop rotation, hybrid rotation and integrated pest management - as a precautionary measure to help prevent it from occurring. Insects and weeds already evolve and develop tolerance or resistance to their environment, so biotechnology can potentially better manage this evolution in resistance.

MYTH: Genetically modified corn kills Monarch butterflies.

FACT: In May 1999, Nature magazine published a letter from researchers at Cornell University that reported findings suggesting further research is needed

into the relationship between pollen from select strains of Bt corn (corn which has been genetically modified to produce a protein to protect against insects) and the Monarch caterpillar. Since that publication, many university researchers, including others at Cornell, have stepped forward to stress that the Monarch study did not represent natural conditions and that extensive environmental research has established the safety of Bt corn on non-target insects, such as the ladybird beetle, honeybee and the green lacewing, in the natural environment.

Dr John Losey, the Cornell University entomology professor who conducted the research, agreed with the researchers and noted, "Our study was conducted in the laboratory and, while it raises an important issue, it would be inappropriate to draw any conclusions about the risk to Monarch populations in the field, based solely on these initial results."

As with any scientific issue, several studies are needed before conclusions can be made.

MYTH: Biotechnology cannot relieve world hunger.

FACT: Biotechnology can help alleviate hunger worldwide. In the next 50 years the global population is expected to double, reaching more than 8 billion people by 2050. Population growth and diet upgrading will require the world food supply to increase at least 250 percent from its current quantity. The amount of land currently committed to food production - approximately 36 percent of the earth's cumulative land area cannot yield the amount of food needed by this increased population. Although forests could be cleared to obtain needed acreage, a better approach is to find ways of getting greater crop yield from existing land. Biotechnology can increase the quantity of the harvest by addressing the factors that traditionally deplete crops such as pests, weeds, drought and wind. Plants from biotechnology can deal with these hardships and dramatically increase the percentage of crops that survive and are harvested each year.

MYTH: The long-term effects of foods developed using biotechnology are unknown.

FACT: From years of research, scientists know that the benefits of food biotechnology are enormous. The scientific consensus is that the risks associated with food biotechnology products are fundamentally the same as for other foods. Current science shows that foods produced using biotechnology are safe to consume and a host of regulatory authorities including the US FDA, the United States Department of Agriculture and the US Environmental Protection Agency have determined that these products are safe to introduce into the food supply.

While there is no such thing as "zero risk" for any food, consumers can be confident that foods produced using biotechnology meet the same stringent safety standards as foods producing using conventional methods.

FAQs:

1. Are there safeguards to protect against a new plant variety outcrossing to weeds and becoming "out of control?"

Yes there are safeguards against outcrossing in the experimental stage. Outcrossing is the unintentional breeding of a domestic crop with a related species.

Great care is taken to develop new plant varieties that have no weed relatives, do not outcross to weed relatives or whose weed relatives exist only in regions where the domestic crops are not grown. Like traditionally bred plants, a new plant cannot confer its traits on an unrelated plant species.

2. What if a plant pest - such as an insect or a plant disease - develops a resistance to a protective trait conferred through plant biotechnology?

Adapting to a changing environment is the natural survival mechanism of all living organisms. Through the natural process of genetic change and adaptation, it is always possible for an insect population or a plant disease strain to build a resistance to a chemical insecticide or fungicide, a protective trait in a plant or to any number of the techniques used to fight plant pests. Nevertheless, to help reduce the potential for resistance development, consideration must be given to resistance management techniques for genetically modified plants.

Traditional pesticides have been brought to market for decades without plans in place to delay resistance. By contrast, the development of some of the first genetically modified plants included almost a decade of research to minimise the potential of resistance development. This kind of research had never been done before. The research resulted in strategies to minimise the possibilities of resistance through conscientious programs and carefully chosen genetic traits.

3. Will antibiotic-resistance marker genes make me resistant to the target antibiotics?

No. There is no relationship between an antibiotic-resistance marker gene used in plants and antibiotic resistance in humans. The marker gene is used in research to help researchers distinguish a new plant variety from related plants. When the plants are exposed to the target antibiotic in the laboratory, the new plant variety will continue to grow, unaffected by the antibiotic, allowing the researcher to identify and select for plants that have the desired trait.

An antibiotic-resistance marker gene is not an antibiotic. It produces a protein that allows only plants containing the marker gene to grow in the presence of a specific antibiotic. This protein is broken down in the digestive tract. Therefore, the marker gene product cannot function in the human body. It cannot inactivate antibiotics and the likelihood of an antibiotic resistant gene being transferred from food to bacteria in the human gut is very small.

There are a few issues, which are relevant to Indian context. These are presented below:

Will GM food reduce hunger in developing countries like India?

If hunger could be addressed by techno-logy, green revolution would have done it long ago. The fact is that hunger has grown in India in absolute terms - some 320 million people go to bed hungry every night. Two years back, India had a record food grain surplus of 65 million tonnes. If 65 million tonnes surplus could not feed the 320 million hungry, how will GM food remove hunger? In reality, GM food diverts precious financial resources to an irrelevant research, comes with stronger intellectual property rights, and is aimed at strengthening corporate control over agriculture.

But what about malnutrition? Crops like golden rice can help remove blindness.

This again is the result of misplaced thinking. There are 12 million people in India who suffer from Vitamin A deficiency. These people primarily live in food deficit areas or are marginalised. These are people who cannot buy their normal requirement of food, including rice. If they were adequately fed, there would be no malnutrition. If the poor in Kalahandi, for instance, can't buy rice that lies rotting in front of their eyes, how will they buy golden rice?

Then why is the Indian government experimenting with GM crops and foods?

For two reasons: First, India is under tremendous pressure from the biotechnology industry to allow GM crops. These companies have the financial resources to mobilise scientific opinion as well as political support. Second, agricultural scientists are using biotechnology as a Trojan horse. With nothing to show by way of scientific breakthrough in the past three decades, GM research will ensure livelihood security for the scientists.

What GM crops and food items is India experimenting with?

Besides cotton, genetic engineering experiments are being conducted on maize, mustard, sugarcane, sorghum, pigeonpea, chickpea, rice, tomato, brinjal, potato, banana, papaya, cauliflower, oilseeds, castor, soyabean and medicinal plants. Experiments are also underway on several species of fish. In fact, such is the desperation that scientists are trying to insert Bt gene into any crop they can lay their hands on, not knowing whether this is desirable or not.

What does the field trial data of GM products, including Bt cotton, in India reveal?

Bt cotton field trials were a sham. In three years of research trials, the experiments were not conducted as per scientific norms. And yet, the GEAC (Genetic Engineering Approval Committee, ministry of environment & forests) had approved the results. The experiment only showed that such products are not suitable for Indian conditions. If only the same attention had gone to more sustainable farming systems, India would have been able to create a unique model of agriculture where farmers are not forced to commit suicide, where the land is not polluted, and where water is not poisoned. GM crops experiments show that the country is fast moving into a hitherto unforeseen era of biological pollution, which will be more unsustainable and also destructive to human health and environment.

But India's Biological Diversity Act 2003 does provide for an environmental assessment of GM crops?

No, not at all. Genetic engineering is moving several times faster than the legal instruments. Transgenic crops and animals in essence go against the very foundation of the biological diversity that we are trying to protect.

What role should the GEAC play?

GEAC should emphasize biological risk assessment. GEAC should regulate genetic technology like the US Recombinant Advisory Committee (RCA) does for genetically engineered drugs. RCA makes it mandatory for companies to provide a list of negative and harmful impacts and minimizes that impact before approving for commercial sale. As a result, the approval process takes 25 years. Unfortunately, GM research in India is not being made to evaluate potential harm to human health and environment. This is because the GEAC does not want the companies to spend more on research.

Does GM technology threaten our genetic resources and traditional knowledge?

We have already lost control over our plant, animal and microbial genetic resources. A copy of roughly 1,50,000 plant accessions that have been collected in India, are with the US department of agriculture. India has no control over these resources. At the same time, India is now busy documenting traditional knowledge, so as to help the American companies know the uses of the plant species they have got from us. Further, Trade-related Intellectual Property Rights (TRIPs) allows patents on genes and cell lines, which will block India's agricultural research leading to what I have always termed as a scientific apartheid against the developing countries.

Positive Impacts of GM crops

For the development of improved food materials, GM has the following advantages over traditional selective breeding:

- Allows a much wider selection of traits for improvement: e.g. not only pest, disease and herbicide resistance (as achieved to date in plants) but also potentially drought resistance, improved nutritional content and improved sensory properties
- It is faster and lower in cost
- Desired change can be achieved in very few generations
- Allows greater precision in selecting characteristics
- Reduces risk of random occurrence of undesirable traits.

These advantages could, in turn, lead to a number of potential benefits, especially in the longer-term, for the consumer, industry, agriculture and the environment:

- Improved agricultural performance (yields) with less labour input and less cost input
- Benefits to the soil of “no-till” farming practice
- Reduced usage of pesticides and herbicides
- Ability to grow crops in previously inhospitable environments (e.g. via increased ability of plants to grow in conditions of drought, soil salinity, extremes of temperature, consequences of global warming, etc.) Improved sensory attributes of food (e.g. flavour, texture, etc.)
- Removal of allergens or toxic components, such as the research in USA to produce a non-allergenic GM peanut (University of Arkansas) and a non-allergenic GM prawn (Tulane University); and in Japan, to produce a GM non-allergenic rice.
- Improved nutritional attributes such as:
 - Ingo Potrykus's EU research project jointly funded by the Rockefeller Foundation, resulting in increased Vitamin A content in rice, which will help to prevent blindness among children in Southeast Asia;
 - the announcement in September 2003 by Edgar Cahoon and his team at the Donald Danforth Plant Science Center in Missouri that by inserting a gene extracted from barley into a common type of field corn, they have created a strain that grows with six times the usual amount of vitamin E, a powerful antioxidant.
- Improved processing characteristics leading to reduced waste and lower food costs to the consumer.
- Prevention of loss of species to endemic disease (e.g. the Cavendish dessert banana which is subject to two fungal diseases that have struck Africa, South America and Asia, but could be relieved by GM development of a disease-resistant version).

GM has huge potential for mankind in medicine, agriculture and food. In food, the real benefits are not the early instances that have been appearing so far, but its longer-term benefit to the world - and especially the developing countries - its potential for developing crops of improved nutritional quality, and crops that will grow under previously inhospitable conditions (see above), thereby contributing to alleviating hunger and malnutrition, while helping to prevent the otherwise inevitable future pressure to encroach on natural resources. Even today, there are 840 million people. 800 million of them in the developing countries and 200 million of them children, who regularly do not receive enough food to alleviate hunger, still less provide adequate nutrition. 24,000 people die of malnutrition-related causes daily. That situation will be greatly worsened as a result of the world's escalating population over the coming decades.

There are those who allege that "scientists claim that GM will solve the problem of world hunger". This is a familiar "straw man". It is frequently argued by some that there is more than enough food to feed the world and all that is needed is "fairer distribution" (which so far mankind has signally failed to achieve) – or a variant of that, "the real problem is not shortage of food, it is poverty". Whatever may be done by way of improved yields through conventional methods, attempted population control and more effective distribution would, however, be inadequate for the future. There are probably enough cereals to feed the present world population (if only they could be distributed to the right places at the right times and could be afforded). But there will be substantial shortfalls in cereals in the next two decades. Moreover, "world hunger" is a complex not only of inadequate quantity where it is needed but also of inadequate quality i.e. for vast numbers of people the lack of foods with the necessary micronutrients and of clean water, for reasonable nutrition and health.

However, in decades to come, with the expected substantial increase in the world population, mostly in the poorest, least developed countries, the demand for increased agricultural land and for water will greatly increase. The important point is not only how to feed the world now but addressing and trying to solve the problem of "How shall mankind feed the world in a few decades from now?" Of course the problem that has huge political and economic dimensions will not be solved by GM alone, or even by science alone -- but will certainly not be solved without the contribution of science, including GM.

Food scientists and technologists can support the responsible introduction of GM techniques provided that issues of product safety, environmental concerns, ethics and information are satisfactorily addressed. so that the benefits that this technology can confer become available both to improve the quality of the food supply and to help feed the world's escalating population in the coming decades.

Negative Impacts of GM crops

There are following unintended impacts on environment, health, markets

Environment:

Unintended environmental impacts include harming non-target and/or beneficial species in the case of crops with engineered insecticidal properties, as well as the development of new strains of resistant pests. Additionally there is concern that pollen from genetically engineered herbicide-resistant crops could reach wild, weedy relatives of the crop and create so-called superweeds. This is of particular concern in the U.S. with crops such as canola and squash.

Health:

At present, there is no evidence to suggest that GM foods are unsafe. However, there are no absolute guarantees, either. Unintended health impacts from GMOs concern allergens, antibiotic resistance, decreased nutrients, and toxins.

- **Allergens** - Because protein sequences are changed with the addition of new genetic material, there is concern that the engineered or modified organism could produce known or unknown allergens. A recent National Research Council committee report on GMOs recommended the development of improved methods for identifying potential allergens, "specifically focusing on new tests relevant to the human immune system and on more reliable animal models."
- **Antibiotic resistance** - Plant genetic engineers have frequently attached genes they are trying to insert to antibiotic resistance genes. This allows them to readily select the plants that acquire the new genes by treating them with the antibiotic. Sometimes these genes remain in the transgenic crop that has lead critics to charge that the antibiotic-resistance genes could spread to pathogens in the body and render antibiotics less effective. However, several panels of antibiotic-resistance experts have concluded that the risk is miniscule.
- **Decreased nutrients** - Because the DNA of genetically engineered plants is altered, there is concern that some GMOs could have decreased levels of important nutrients, as DNA is the code for the production of nutrients. However, it must be noted that nutritional differences also have been documented with traditionally bred crops.
- **Introduced toxins** - Residual toxins resulting from introduced genes of the bacteria *Bacillus thuringiensis* in so-called Bt crops are unlikely to harm humans. This is because the toxin produced by the bacteria is highly specific to certain types of insects. Prior to its inclusion in GE/GM crops, Bt has been used as a biological insecticide, causing no adverse effects in humans consuming treated crops. See the World Health Organization's Bt monograph for additional details.
- **Naturally occurring toxins** - There is concern that genetic engineering could inadvertently increase naturally occurring plant toxins. However, traditional plant breeding also can result in higher levels of plant toxins.

Markets:

Unintended market impacts include lower prices and higher costs for farmers, as well as lost premiums and markets. Bans on GM imports or moratoriums on approving new GM varieties/hybrids reduce the number of export destinations for co-mingled GM and non-GM crops. This results in depressed crop prices due a greater percentage of crops needing to be used domestically. Additionally, moratoriums on new GM varieties/hybrids and mandatory labeling practices in some countries, including some of the U.S.' larger export partners, may necessitate separate handling of grain. The cost for this is ultimately born by U.S. farmers. In 1999, A.E. Staley and Archer Daniels Midland announced that they would not accept grain produced from hybrids containing genetic material that is unapproved for export. And, Illinois Cereal Mills, owned by Cargill Inc., increased its contracts for non-GMO crops.

Pollen from GM crops can contaminate non-GM crops, especially those certified organic, which are subject to a zero-GMO tolerance. Stray pollen could render a crop ineligible for organic or specialty premiums on contracts requiring non-GM varieties/hybrids. Compounding the problem is the fact that many genetic tests for GMOs result in false positives.

In 1999, Frito Lay and Novartis-owned Gerber announced that they would not be purchasing GM crops/ingredients for their products. Internationally, several companies have made similar announcements, though not for their U.S. product lines. In June 2000, Novartis became the first multi-national to announce that it would not be purchasing GM crops/ingredients for any of its products worldwide, including those for the U.S. market.

Moral Issues

"Moving genes from animals to plants gets you into a whole moral, religious, and political firestorm..."

This statement illustrates the primary contention point for the most common ethical-moral argument against GMOs. For those who believe that humans do not have the right to create life that humans are stewards of the earth's species, or that humans are equals with other species, combining genes in ways that would not occur in the normal process of evolution conflicts with their personal philosophy of life.

However, the argument has been made that genetic engineering is morally justified as it can be used to alleviate disease and starvation. While the argument for alleviating disease is supported by the case of genetically engineered human insulin and not-yet-commercialized projects that seek to deliver vaccines via food

crops, the argument for alleviating hunger has yet to be borne out. GM crops have yet to increase yields on par with hybridization in corn, and it must be remembered that simply growing more of a crop does not guarantee that it will reach people who are starving. A member of the European Parliament, speaking at the *European Voice* Conference on GMOs in Brussels in March 1999, blasted biotech [companies' public relations campaigns] saying while they "attempt to convince people they just want to save the environment and feed the starving, -- people know that wealthy companies have not been created to feed the poor." That said, on August 3, Monsanto announced that it would not charge licensing fees for the use of its patented technology for producing golden rice.

How India fits in the picture of GM Crops?

In India, experiments have been carried out and GM crops like the Golden Rice (which is rich in proteins) have been used. Unfortunately, the GM business is owned by top multi-national companies and agri-business is only for vested interests. One of the prime fears related to biotechnology is that the GM crops may lead to a monoculture and devastate the biodiversity that maybe like a self serving bio weapon on a target nation. This decade is crucial for India in which it will have to take decisions on the prospect of GM crops. While experimentation is going on in India, we need to retain our traditional knowledge and practices. The so-called coarse grains like bajra and millets may be more nutritious for the farmers (or even the affluent) than rice and wheat. For better nutritional security, we may need traditional food habits and food grains, cereals and milk suited to our agricultural zones.

Warning bells

INDIA is the third largest producer of cotton after China and the U.S. The Maharashtra Hybrid Seeds Co. Ltd Mahyco is one of the largest and most trusted seed companies in India. In 1998, after 8 years of negotiation, Monsanto became a 50% shareholder in the company and received approval to conduct countrywide field trials. The data compiled was never made public.

On the 26th of March 2002 the Genetic Engineering Approval Committee of India, gave the conditional clearance to Monsanto and Mahyco for commercial planting of the genetically engineered *Bacillus thuringiensis* (Bt.) cotton in four states of southern and central India.

In June 2002, about 55,000 cotton farmers decided to grow Bt cotton, which was developed by inserting a gene of bacteria into the plant's genome to enable it to resist bollworm, a major pest for cotton.

In the first few months the farmers were delighted with the crop since it grew fast

and looked healthy. Most satisfying was that the leaves were not being eaten by worms.

Unfortunately, in the fourth month, the Bt cotton stopped growing and producing new buds while the existing cotton bolls did not get any bigger. The crop then wilted and dried up at the peak bolling stage. This was accompanied by leaf-drooping and shedding. There was also bursting of immature bolls and heavy infestation of bollworm. In the state of Andhra Pradesh 79% of the crop was lost. In Madhya Pradesh 100% of the crop was lost. In Maharashtra, the Bt crop has failed across 30,000 hec. In Gujarat, it was completely destroyed by the bollworm. Subsequently, about 200 farmers committed suicide.

The Bt. cotton failure has cost the farming industry a total loss of Rs. 1128 million or twenty million euro in 105000 acres across the country in one cropping season. The law states that any company that provides poor quality seeds, the performance of which does not match the claims made by the company, is to be held liable for the failure of the variety. Despite this Monsanto has refused to acknowledge the failure or provide any compensation to the farmers.

Monsanto claimed that the crop would be completely pest resistant. Results have clearly shown that the BT cotton crop was devastated by pest attacks. When the BT toxin in the crop proved ineffective in 90 days the farmers used pesticides bought from Monsanto. The spraying of these expensive pesticides had an adverse affect on the crop. The plants developed the leaf curl virus and the root rot disease and were destroyed. Monsanto took no responsibility.

Monsanto claimed that the crop would be resistant to the bollworm provided that there was a 20 percent refuge crop of non-BT cotton planted alongside the BT crop. This would ensure that the bollworm would attack only the conventional crop. In reality however the bollworm not only attacked the conventional crop but also devastated the bt crop. A relative of the American bollworm called the pink bollworm developed with immunity to the BT toxin.

Also in these instances, the 20% refuge of conventional crop actually yielded a better harvest. In most cases it was only the conventional refuge crop that survived. Again Monsanto took no responsibility.

Monsanto claimed that there would be no attack from any other pests. But in reality sucking pests like Jassids, aphids and Thrips thrived on the Bt. Cotton. The sprays bought from Monsanto to control these pests were seven times more expensive than conventional sprays even though Monsanto had originally claimed that they would not be necessary.

Monsanto claimed that the yields of the bt cotton crop would be 15 times higher than the average yield of conventional cotton. But nowhere in the surviving farms did the crop exceed the average yield. A good bt crop produced 60 cotton bolls per plant while the conventional plant produced 250 to 300. The seeds cost the farmers four times more than the conventional seeds even though they have to be bought on a yearly basis, as they cannot reproduce. The labor costs also increased by 50%.

Following the dire publicity over the performance of its GM (Bt) cotton in India, and with many poor Indian farmers facing ruin, Monsanto-Mahyco came up with findings which it provided to the Indian government showing that it had been a

great success. Greenpeace-India sent its own researchers to check up on how the data had been compiled and, amongst much else, the researchers collected testimonies from farmers who said that they had been advised by the company to inflate their real yield figures.

Monsanto claims that the negative publicity against them has been fabricated by competitors. They do not believe that they owe the Indian farmers any compensation and plan to continue with the sale of their seeds.

In studies carried out, it has been demonstrated that gm crops transfer their genes to soil fungi and bacteria. The affected fungi and bacteria then behave in abnormal ways and diminish their function in breaking down organic material, which makes nutrients available to plants. The soil will become progressively less fertile. After a few seasons of planting the gm crop the soil will not be able to host any other conventional crop. If farmers wish to switch back to conventional crops it could take a whole season to rehabilitate the soil. The economic consequences of which are clearly unfavorable. There is also the added cost of nutrients and fertilizers necessary to regenerate the soil. However the most dangerous threat is that after many seasons it could be impossible to revert back to the planting of any conventional crop. Because by then the soil could be completely infertile.

GM crops are genetically manipulated so that they die after one season and cannot reproduce. This is referred to as the terminator gene in the plant. It is promoted as a means of preventing transgenic contamination to other crops. This has proved to be false. It actually spreads not only male sterility but also herbicide tolerance in other crops. The pollen from the crops carrying the Terminator will infect the fields of farmers who either reject, or cannot afford the technology.

Any farmer whose crops are contaminated will then have to label all their produce as "gm contaminated". Monsanto can also sue them for the theft of genes.

On the 2nd of January 2003 it was reported that the plan for the "protato" was presented at a conference in London by G. Padmanaban who as director of India's prestigious Indian Institute of Science had signed a secret deal with Monsanto that even his fellow scientists of the Institute knew nothing about. The genetically engineered potato that is now being offered as part of an anti-hunger strategy has genes from the plant amaranth. Particularly when fed to children under the age of 13 the genetically engineered potato will in fact create malnutrition. It denies to children the other nutrients available in grain amaranth and not available in potato. This genetically engineered potato will in fact spread iron and calcium deficiency in children. The already malnourished children who will be the main consumers of the potato stand to suffer even greater deficiencies.

The cow has been made sacred in India because it is a keystone species for agro-ecosystems. And cow dung, biomass and biodiversity are the non-violent organic alternative to genetic engineering and chemicals. Farmer's organizations in India and in Africa are saying "no" to GMO's on the basis of their freedom to

choose to be organic. This means being free of genetic contamination that results from GM crops. Genetic contamination robs farmers of their freedom to be GM free. Organic agriculture in India is increasing farm productivity by 2 to 3 times, increasing farmers' incomes, and protecting public health and the environment.

A major factor in agriculture is the availability of water. Bt cotton consumes much more water than non-Bt hybrids do. The ruin faced by the farmers is of critical interest to India, which has the world's largest acreage of cotton (25% at nine million hectares) but accounts for just a little over 12% of the production. The BT cotton disaster decreased production dramatically creating havoc in the Indian economy.

On the 5th of January 2004, the Indian government announced details of a six-year plan to develop new genetically engineered crops that will provide better nutrition. Government scientists say this kind of research is urgently needed to improve the health of the developing world. The "Plant Genome Research Road-Map", as it's called, was unveiled at the Indian Science Congress.

The Indian movement against GM will continue to fight any genetic manipulation of crops that might be proposed by the government or multinationals. Farmers across the country have declared themselves Gm free and have been staging protests and forming movements like Quit India Monsanto and Cremate Monsanto. Activists in India believe that neither affluent populations nor those struggling to survive have the need for an inadequately tested technology that has the potential to cause devastation on a global scale in the years to come. We have no need for a technology that has proved beyond doubt to be fatal to the environment.

India Becoming a Dumping Ground for GE Crops

As the world wakes up to human health and environment nuisance from the genetically modified (GM) crops, India is fast turning into a dustbin for the new technology.

In March, Western Australia became the first Australian state to ban outright planting of GM food crops. Its Premier, Geoff Gallop, said he did not want to jeopardize his state's canola industry at a time when international consumer sentiment was opposed to GM crops. Within a few days of this decision, Victoria imposed a four-year moratorium on the cultivation of GM oilseeds rape to protect its clean and green image. South Australia and Tasmania have already banned GM crops. Four states imposed a moratorium on growing GM crops in a space of five days.

In the United States, Mendocino county in California became the nation's first to ban the raising and keeping of genetically engineered crops or animals. In March, the hilly state of Vermont, in a historic decision, voted overwhelmingly to support a bill to hold biotech corporations liable for unintended contamination of conventional or organic crops by genetically engineered plant materials. This bill is the first of its kind in the world that aims to protect a farmer from being sued by the seed companies if his crops are contaminated with GMO material.

In Britain, the dramatic turnaround by Bayer Crop Science to give up attempts to commercialize GM maize, have ensured that the country remains GM free till at least 2008. Despite Tony Blair's blind love for the industry, tough GM regulatory regime came in the way of the adoption of the technology. In Japan, consumer groups announced their intention to present a petition signed by over 1,000,000 people to Agriculture and Agri-Food Minister, Bob Speller. The petition calls for a ban on GE wheat in Canada. Japan is one of the biggest markets for Canadian wheat.

In April, however, the Genetic Engineering Approval Committee (GEAC) in India approved another Bt cotton variety for the central and southern regions amidst reports that the go ahead came without adequate scientific testing. The approval also comes at a time when the US Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) is seeking public comment on petitions from Mycogen Seeds to deregulate two lines of genetically engineered insect-resistant cotton. APHIS is seeking public comment on whether these cotton lines pose a plant pest risk.

Such has been the casual approach to regulate the most-controversial technology that it has become practically difficult to keep track of the new GEAC chief. They keep on changing at a pace faster than that expected from musical chairs. At the same time, while Britain had set in place a tougher regulatory regime making the companies liable for any environmental mishap, India continues to ignore the warning. The regulations that the GEAC had announced at the time of according approval to Bt cotton in 2002 were only aimed at pacifying the media. The GEAC has not been held accountable for the deliberate attempts to obfuscate the public opinion in an effort to help the seed industry make a fast buck.

It is a widely accepted fact that the safety regulations, including the mandatory buffer zone or refuge around the BT cotton fields, were not adhered to. Yet the Ministry of Environment and Forests refrained from penalizing the seed company. Nor did it direct Mahyco-Monsanto to compensate crop losses that the farmers suffered in the very first year of planting Bt cotton in 2002-03. That the crop had failed to yield the desired results was even highlighted in a parliamentary committee report.

Not all GM decisions are taken in accordance with scientific principles. While a NGO petition before the Central Vigilance Commission (CVC) seeking an enquiry into the entire monitoring, evaluation and approval process was ignored, the US authorities have launched an investigation into reports of alleged bribing of Indonesian government officials who approved Bt cotton. Both the US Department of Justice and the Securities and Exchange Commission are examining whether a former consultant to Monsanto made an improper US \$50,000 payment in early 2002.

Monsanto spokeswoman Lori Fisher was quoted as saying: These are serious allegations and we will continue to cooperate. Reuter reports that the company is one of the world's leading developers of genetically modified seeds, but has had trouble getting some of its biotech crops approved in foreign countries, including biotech cotton introduced in Indonesia in 2001. Monsanto closed down the biotech cotton sales operations in 2003 after two unsuccessful years that came amid complaints over yields and pricing.

India has meanwhile become a favored destination for the biotechnology industry that is virtually on the run from the US, European Union and Australia. In Europe, a 2002 survey showed 61 per cent of the private sector cancelled R&D as a result of moratorium actions. With highly critical reports of regulatory mechanism coming in from respectable independent institutions, the trend in US is also towards still more tougher regulations thereby forcing biotechnology companies to grow the next generation of GM crops in abandoned mines, using artificial lighting and air filtration to prevent pollen movement.

In India on the other hand, besides cotton, genetic engineering experiments are being conducted on maize, mustard, sugarcane, sorghum, pigeonpea, chickpea, rice, tomato, brinjal, potato, banana, papaya, cauliflower, oilseeds, castor, soyabean and medicinal plants. Experiments are also underway on several species of fish. In fact, such is the desperation that scientists are trying to insert Bt gene into any crop they can lay their hands on, not knowing whether this is desirable or not. The mad race for GM experiments is the outcome of more funding from the biotech companies as well as support from the World Bank, FAO and the Consultative Group on International Agricultural Research (CGIAR).

Interestingly, while the rest of the world is stopping GM research in the tracks lest it destroys the farm trade opportunities due to public rejection of the genetically engineered food, Indian Council for Agricultural Research (ICAR) merrily continues to sow the seeds of thorns for agricultural exports thereby jeopardizing the future of domestic farming. But then, who cares for the farmers as long as GM research ensures the livelihood security for a few thousand agricultural scientists.

Future of GM crops in India and the world

Genetically modified crop technology has revolutionized agriculture in the United States, Canada, China, and Argentina. It exhibits the potential to have much wider impact, solving many of the current problems in agriculture worldwide. The types of GM crops that may become available in the future could boost crop yields while enhancing the nutritional value of staple foods and eliminating the need for inputs that could be harmful to the environment. While the environmental, health, and economic risks of GM crops should be carefully studied before full-scale adoption, the types of GM crops that are already available have thus far largely proven to be beneficial to agriculture and even to the environment, without evidence of adverse health or environmental impacts.

In 2002, 58.7 million hectares of GM crops were grown worldwide with two thirds in the US. Other countries growing GM crops are Argentina, Australia, Bulgaria, Canada, China, Columbia, Honduras, India, Indonesia, Mexico, Romania, South Africa, Spain and Uruguay.

Globally, nearly 12 million hectares of GM maize were grown in 2002. In the US, around 25% of the maize harvest is genetically modified. In Europe, commercial growing of GM Bt maize is already underway in Spain.

Around 70% of the US soya planted is GM. In Argentina the figure is 95%. Currently, around 46% of the entire global soya crop is GM.

Yet, in other than the four countries mentioned above, the GM crop movement has had little or no impact. In those parts of the developing world where an agricultural revolution might be most welcome, the Gene Revolution has yet to be embraced. Why is this so?

For one thing, the Gene Revolution began in a different way than the Green Revolution. GM crops were first created within the context of the biotechnology industry to provide enhanced agricultural technologies to the industry's primary customers—farmers in the industrial world. These crops were not meant at the outset to be a life-saving technology for the developing world. Although it is almost certainly possible from a scientific and technological standpoint to create GM crops that would be beneficial to developing-world farmers, neither producers (the biotech industry) nor consumers (developing-world farmers) have sufficient economic incentives for this to happen. In fact, the enormous costs of producing each GM crop variety could prove to be a disincentive for the industry to develop "orphan GM crops" that would benefit developing-world farmers.

Additionally, even if the biotech industry were to develop GM crops that are beneficial to farmers in the developing world, the poorest of those farmers would

not be able to afford GM crop seed instead of conventional varieties, much less purchase new GM crop seed for every planting season, as biotech patents would require them to do.

Finally, the current political situation is not as conducive to promoting this new agricultural movement as it was for the Green Revolution. For all the potential that GM technology holds, there are many challenges to be overcome if GM crops are to truly introduce a “Gene Revolution” worldwide.

In future the following goals need to be met and their related challenges overcome:

1. Agricultural biotechnology must be made affordable to developing-world farmers. Unless this condition is met, farmers may not see that it is in their best interest to use GM crops, despite the significant benefits those crops could provide.

During the Green Revolution, the new HYV seeds and accompanying chemicals were more expensive than the landrace seeds that developing-world farmers typically had used. Therefore, loan systems and cost-reduction programs were established regionally in which farmers’ eventual profits from increased production could be used to reimburse lenders. In many settings, these programs proved to be no longer necessary several years after their successful adoption. Current R&D costs for genetically modified seeds are even higher than the R&D costs for the Green Revolution’s HYV seeds. At the price that U.S. farmers currently pay, GM seeds would be unaffordable to most developing-world farmers. Cost-reduction programs and loan systems similar to those that were established during the Green Revolution must also be established for the Gene Revolution; however, establishing such systems is more difficult now because of higher costs and because the seeds are produced by the biotech industry rather than by agricultural scientists in the public sector.

2. There is a need for larger investments in research in the public sector.

Numerous studies (e.g., Alston et al., 1995; Conway, 1998; Shoemaker et al., 2001) have shown the importance of public sector R&D to agricultural advancements, including the advancements of the Green Revolution. During the Green Revolution, partly because the R&D and its products were almost entirely in the public domain, intellectual property issues were not a barrier to scientists, for example, taking seeds from one region of the world, hybridizing them with seeds from another region, and producing new seeds to benefit yet another region. Today, however, the production and distribution of GM crops are largely within the domain of the biotech industry, and IP issues are central to the development of GM seed. While IP laws protect the rights of GM seed creators in industry, those laws are currently an impediment to disseminating the necessary knowledge and technology to those parts of the world that need them. Therefore, public-sector research is essential if the GM movement is to assume revolutionary proportions. Partnerships between the public and private sectors

can result in the more efficient production of GM crops that are useful to the developing world and expand the accessibility of those crops and their associated technologies to developing-world farmers.

3. To garner the level of public interest and support that can sustain an agricultural revolution, agricultural development must be regarded as being critically important from a policy perspective, in both donor and recipient nations. Without public policy support, cooperation among the many stakeholders in the Gene Revolution will be stymied.

For 30 years after World War II, policymakers viewed agricultural development as being essential to world peace. For that reason, policymakers in both the United States and in Asia and Latin America supported the Green Revolution from the start. The end of the Cold War, however, has not brought about an increase in global stability. Whereas the conflict between East and West has declined, there is a growing divide between rich and poor nations. Unfortunately, with the end of the Cold War, developed nations are concentrating more closely on their domestic political agendas and less on global concerns, and as such have decreased their funding to poorer nations. However, these reductions in aid are not in the best long term interests of even industrialized nations. An increasingly polarized world of the rich versus the poor will result in growing political unrest. Unless developing nations are helped to provide sufficient food, employment, and shelter for their growing populations, the political stability of the world will be further undermined (Conway, 1998).

As population numbers continue to increase, agricultural development is more necessary than ever to eliminate malnutrition and prevent famine, particularly in sub-Saharan Africa. GM crops are seen as a means for addressing those problems. However, policymakers worldwide are far from being a combined force on this issue; the driving force behind improved agriculture is less unified than it was during the Green Revolution. The question of who should assume the task of re-establishing the importance of agricultural development among policymakers is an issue for further inquiry.

4. Policymakers in the developing world must set regulatory standards that take into consideration the risks as well as the benefits of foods derived from GM crops. This goal is crucial to the cooperation of the many stakeholders that are affected by GM crops and also for the sustainability of the GM crop movement in the foreseeable future. A generation ago, the regulatory environment surrounding the Green Revolution was extremely permissive. Scientists could move freely among nations to help breed and plant HYV crops, and there was no stigma attached to eating foods developed from these crops. Today, however, the regulatory world is divided between those nations that permit GM crops to move freely through their food system (e.g., the United States, Canada, China, and Argentina) and those (primarily the EU) that have strict regulations regarding GM crops in their food systems. There are many

possible reasons for the disparity in regulations—differing consumer attitudes, trade issues, and differences in regulatory philosophy among them.

The discord regarding GM crop regulations is currently playing itself out (as of this writing) in a case before the WTO to determine whether the EU's rules on GM foods constitute an illegal trade barrier. In the meantime, policymakers in certain African nations have decided that they cannot afford to permit GM crop planting, even if it is beneficial to their growers and consumers, because they are wary of losing financial aid from the EU if they are seen as taking a pro-GM crop stance. Without regulations that explicitly take into account potential benefits to both farmers and consumers, those nations that might stand to benefit most from GM crops may be discouraged from allowing them to be planted.

At the same time, policymakers worldwide must ensure that risk assessments of GM crops are conducted to address the specific concerns of their regions. A risk assessment of transgene outflow in the United States, for example, is unlikely to be relevant to ecological concerns in Mexico or Africa. In assessing risks, policymakers in developing nations must consider, among other factors, the types of native and agricultural plants that may be affected by the presence of GM crops, traditional farming practices and the desired traits of GM crops that may be planted in their regions in the near term and long term.

References

<http://www.zmag.org>
<http://www.aces.uiuc.edu/asap>
<http://www.afic.org>
<http://www.biomedcentral.com>

Bibliography

<http://www.ucbiotech.org/>
<http://www.newscientist.com/channel/life/gm-food>
<http://www.gmissues.org>