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## Review Article

### GENETICALLY MODIFIED PLANTS: A SYSTEMATIC REVIEW

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#### ABSTRACT

BY means of genetic engineering, genes can be introduced into the same plant or animal species for the improvement of their beneficial qualities. This technology has led to the commercial production of genetically engineered [GE] crops on approximately 250 millions acres worldwide. These crops contain desired genes that make them pest resistant and insect resistant, and also in other GM crops, genetic engineers improved their nutrient quality and storage life-time by the insertion of desired genes. In this review, techniques used in genetic modification of plants, their application and negative impacts on the environment will be addressed. Also safety assessment raised regarded GE crops and food, environmental release of GM crops, status of GM crops in India and their economics will be covered in this review.

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#### INTRODUCTION

Plant genetic modification (also known as genetic engineering) may be defined as the manipulation of plant development, structure or composition by the insertion of specific DNA sequences. Genetic modification involves altering an organisms DNA. Those plants which are produced by the process of genetic engineering or genetic modification are called genetically modified plants or transgenic plants. These plants carry additional stably integrated and expressed foreign genes from trans-species.

When a scientist modifies the genome of an organism or a plant, they insert a foreign gene into the plant's own genome. This gene might be from other plant species, animal, or from micro-organisms e.g; from bacteria- *Bacillus thuringiensis* resistance to insects. When this bacterial gene (Bt gene) incorporates into the plant's genome, it replicate and expressed like other plant's own genes. The desired character i.e; insect resistance is marked in the modified plant after gene transformation. Not only the genes that are responsible for insect and pest resistance are used in genetic engineering but also those desired genes that enhance the nutrient quality, shelf life time are also used in the genetic manipulation. Like genetic modification, muta-genesis with chemical or physical mutagenes also alter Organism's DNA and induce new variations in the species of interest. Mutation breeding can result in the expression of crop plants of many novel genes, the

effects of which cannot be assessed readily. Spontaneous alteration can lead beneficial as well as negative characteristics in the mutant. Also mutation breeding are not good, if the intension is to creat specific genes. Genetic engineering overcomes the limitations of traditional breeding and allows scientists to use new traits for many kinds of plants and other living things such as fish, insects, bacterium and even humans. Because all living organisms use the same genetic language, different kinds of organisms can understand each other's genetic code .If a new gene is introduced to another organisms cell that will begin to produce that genes particular protein and will display the new trait directed by the gene.

The basic techniques of plant genetic engineering were developed in the early 1980's and the first GM crops became commercially available in the mid-1990s. Since then, GM crops adoption has increased rapidly. In 2008, GM crops were being grown on 9 % of the global arable land (James, 2008). The first GE plants was tobacco, reported in 1983 but no plants were commercially grown until the Flavr Savr<sup>TM</sup> tomato was commercialized in 1994. Although the Flavr Savr<sup>TM</sup> tomato was ultimately taken off the market other commercial crops entered the market most notably large acreage crops, such as canola (*Brassica napus*), Corn, Cotton, Soyabean and most recently alfalfa (*Medicago sativa*).

Three categories of GM crops can be distinguished-

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First generation GM technologies that are being developed include fungal, bacterial and virus resistance in major cereal as well as root and tuber crops (Halford, 2006). Plant tolerance to abiotic stress- such as drought, heat and salts is also being worked on intensively. Second generation GM technologies include product quality improvements for nutrition and industrial purposes. Examples are oilseeds with improved fatty acid profiles, high amylose maize staple foods with enhanced content of essential aminoacids, minerals and vitamins. (Jefferson Moore and Traxler 2005, pew initiative on food and Biotechnology, 2007). Third generation GM crops involve molecular farming where the crop is used to produce either pharmaceuticals such as monoclonal antibodies and vaccines or industrial products such as enzymes, and biodegradable plastics (Moschini 2006, Halford, 2006). Genetically modified crops plants and GE foods made from them has revolutionized the agricultural sector of the world by overcoming the problem of Conventional breeding and also plays an important role in order to meet the demands of growing population.

### **Gene Transfer Strategies**

Gene transfer in plants is achieved using three different methods :-

#### **Agrobacterium Mediated Gene Transformation**

The first exploits nature's own genetic engineer, the naturally occurring soil bacterium *Agrobacterium tumefaciens* (Bevan M.) Which infects wounds on some plants to form a tumorous growth called as ' Crown gall'. The tumour formations result from integration of a DNA fragment (the T-DNA) from the *Agrobacterium* into the plant's genome. As well as inducing tumour growth, genes present in the T-DNA cause the tumorous cells to produce compounds on which the bacteria feed. The T-DNA is present in a plasmid (The Ti or tumour inducing plasmid), a closed circle of extra- chromosomal DNA, rather than the bacterial chromosome. This means that it can be isolated and manipulated to remove the genes that would be inserted into a plant by wild *Agrobacterium* and replace them with novel genes. After infection of plant material with the modified *Agrobacterium*, whole plants can be regenerated from the resulting genetically modified tumour like clumps (callus) by application of plant hormones.

#### **Direct Gene Transfer**

##### **Gene transfer using particle Bombardment technique**

The second widely used method is particle bombardment, The first genetically engineered plants were produced in middle 1980s (Horsch *et al.* 1985) and developed interest of genetic engineers in the production of transgenic plants for both basic and applied work. In this method the DNA is coated onto the surface of microscopic gold particles which are then shot into plant cells using a burst of helium gas. Some of the DNA is washed off the particles and becomes integrated into the plant genome. As with the first method, Whole plants can be regenerated from genetically modified cells by careful culturing and application of plant hormones. This method which has acquired the unfortunate name of biolistics has been particularly successful in the production of genetically modified cereals (Barcelo *et al* 1994).

### **Gene transfer by microinjection technique**

The microinjection technique involves the use of injection needles with diameters far wider than cell diameters for delivering DNA into wound sites within tissues. However, at the same time it destroys those cells which are in direct contact with the injected DNA. To integrate the DNA must gain entry to intact cells adjacent to the wounded site. For transformation, microinjection systems are designed for speed and operational simplicity as these factors govern the total number of cells that can be manipulated. To facilitate rapid injection rates protoplasts with partially reformed cell walls can be attached to solid support (glass cover slips or slides) with poly-L lysine or artificially bound substrate without damaging the cells. Several advantages are associated with the microinjection technique. First of all, the amount of DNA delivered per cell is not limited by the technique and can be optimized. This improves the chance for integrative transformation. Secondly, the delivery is precise, even into the nuclei of the target cell, again increasing the chance for integrative transformation. Thirdly, the small structure can be injected containing only a few cells and with high regeneration potential, for example, microspore derived and zygotic proembryos. Lastly, it is a direct physical approach and therefore host-range independent.

#### **Electroporation**

This method uses an electrical pulse to introduce DNA into cells. By exposure to electrical shock, the cells become temporarily permeable to DNA, if the required DNA fragment is kept in direct contact with the protoplast membrane, the entry of DNA molecules into the cells is facilitated. Successful DNA transfer through this technique has been shown in bacterial, yeast, fungal, plant and mammalian cells. Among plants, successful gene transfer using electroporation method has been reported in protoplasts of tobacco, petunia, maize, rice, wheat and sorghum. In carrot, maize and tobacco protoplast bacterial CAT genes with different plant promoters has been introduced and efficiently expressed. Electroporation is applicable to both monocot and dicot protoplasts.

#### **Transformation By Plant Viruses**

Third, use of plant viruses for gene transformation. Caulimovirus and the geminivirus (DNA viruses), were the first developed as vectors. The viruses of plants never integrate into the plant genome and are not transmitted through seeds, so stable transformation cannot be achieved

#### **General Procedure Used To Make a Genetically Modified Plant**

- In order to make a transgenic plant, the genetic engineer first of all selects the plant or other organism which contains the gene of interest used for modification of desired plant.
- In the second step location of desired gene from the specific plant is made. After identification, the gene of interest is to be cut out from the plant's DNA using restriction endonuclease enzymes. By using selected restriction endonuclease enzymes, scientists are able to cut the DNA strand at particular points and isolate specific genes.
- Producing multiple copies of the desired gene, it needs to be attached to a vector or carrier. vectors are also used

for transformation. One common means of transferring genes into plants is soil bacterium. *Agrobacterium tumefaciens*, causes a disease called Crown gall in the susceptible plants by inserting its genes into plant's DNA.

- Recombinant T-DNA (Plasmid) also contains a dominant selectable marker gene with a plant transcriptional promoter for the selection of transformed cells.
- *Agrobacterium*, that carries a recombinant plasmid with both a selectable marker and a desired transgene are cultured along with the plant cells which needs to be modified.
- In the culture media, the wounded plant cells release some chemical substances (in particular acetosyringone) that attract the *Agrobacterium* and cause them to inject the desired DNA into the cells.
- Only those cells that take up the appropriate DNA and express the selectable marker gene survive to proliferate and form a callus.
- The plant tissue that taken up the genes is then grown into adults plants carrying the transgene.

#### **Selection or Identification of Transgenes**

The plant or animal which has been genetically modified can be identified with the naked eye only in some rare cases. Scientists have therefore developed some advance biotechnological techniques to assist the identification of transgenic plants.

**For example:-** When the plant is to be made genetically modified, At that time Scientists inserts an extra marker gene into the plant. The marker gene helps in the identification of transgenic plant due to some of its characteristics e.g; it can make the plant change colour when exposed to a chemical test. In this way, Scientists can identify the genetic modification of the plant by performing a chemical test and noting the colour of the plant.

#### **Techniques for the Removal of Marker Genes from Transgenic Plants**

In the process of genetic engineering, when the desired gene is loaded in the DNA fragment of plasmid or any other vector, a dominant selectable marker gene with a plant transcriptional promoter is also added that enables the selection of transformed plant cells and tissues. Selectable marker genes encode a product that allows the transformed cells to survive and grow under conditions that kill or restrict the growth of non-transformed cells. Most such genes used in plants are dominant selectable marker that confers resistance to antibiotics or herbicides. The commonly used selectable marker gene include those conferring resistance to the antibiotics kanamycin (npt II gene, encoding neomycin phosphotransferase) and hygromycin (HPT, encoding hygromycin phosphotransferase) and herbicides phosphinothricin (The BAR gene, codes for phosphinothricin acetyltransferase) etc.

Following transformation, the continued presence of the selectable marker genes in GM plants become unnecessary and undesirable. Herbicide resistance marker genes in transgenic plants could be transmitted to the wild relatives of the crop by means of pollen transfer. The presence of antibiotic resistance

marker genes also poses a threat to the ecosystem. Horizontal antibiotic resistance gene transfer from plants to environmental or medically related bacteria or from plant products consumed as food to the gut flora of man or animals and lead to the spread of antibiotic resistances in pathogenic micro-organisms.

In addition to environmental and health concerns, there are also practical reasons for the removal of unnecessary marker gene from plants. The possibility of removing unwanted marker genes following plant transformation allows the same marker to be used for the sequential addition of further transgenes because the number of selectable marker genes used in gene technology is limited and not all of these are well adapted to all transformable plant species. Also if the multiple copies of marker genes remain in the plants after gene transfer it leads to the silencing of the required transgenes through homology dependent gene silencing mechanisms due to which the desired transgene cannot expressed its trait in the plant exactly. However there is no evidence that the transgenic markers presently in use can cause negative effects on the expression of transgenes as well as on environment and human health. Recently, Scientists have developed a number of methods for the removal of selectable marker genes from the transgenic plants after gene transformation. These methods include

- Co- transformation (i.e; separate transformation of marker and transgene.
- Site-specific recombinase mediated marker deletion (e.g; Cre/Loxp), FLP/FRT and R/RS Site-specific recombination systems.
- Transposon based expelling system (e.g; AC transposon).
- Intra chromosomal recombination.
- Transformation by marker genes not based on herbicide or antibiotic selection.

#### **Co-Transformation**

Co-transformation is a method of transformation used in genetic engineering of plants in which two distinct transgene constructs present in the same transformed line of *Agrobacterium tumefaciens* are used. These two transgenes are inserted into two different T-DNA elements present in the same "super -binary" plant transformation vector. one of these gene constructs contain the selectable marker gene and the other contains the desired trait transgene. Co-transformation is a simple method used for the removal of selectable marker genes from the genetically modified plants by Segregation and recombination that occurs during sexual reproduction of these plants. However, Co-transformation method cannot be used for the removal of marker genes in those plants which propagate vegetatively. These procedures require fertile plants and are time consuming. In the Co-transformation method, mutated *Agrobacterium* Vir gene is inserted into T-DNA which allows the formation of marker free plant DNA population. Recently, a novel marker gene has been characterized, da01 encoding D-aminoacid oxidase can be used as negative marker (negative selection) for the production of marker free transgenic plants by Co-transformation.

#### **Simple Microbial Recombinase Based System**

Simple microbial recombinase based system for the removal of selectable marker genes from the transgenic plants is based on

the phenomenon of site-specific recombination of bacteriophages. There are three site-specific recombination systems that might be useful for the production of marker free transgenic plants Cre/10xP system where Cre recombinase enzyme of bacteriophages has been used to excise marker genes cloned between 10xP recombination sites, FLP/FRT recombination system from *saccharomyces cerevisiae* (yeast) where FLP recombinase acts on the FRT sites and R/RS recombination system from *zygosaccharomyces rouxii* where recombinase catalyse recombinational excision between RS recognition sites. In these systems, removal of SMG would require recombinase expression in transgenic plants. The recombinase gene and its own associated marker gene must be separated from the desired transgene by genetic segregation. However these site-specific recombination systems are not widely used for removal of SMG's because they require sexual crosses and can not be used in vegetatively propagated plants. Recently CLX vector system and GST-MAT vector system (multi-auto- transformation) are used. These two systems including oncogenes for cell proliferation and regeneration of transgenic plants to express recombinase genes, which include excisions of SMGs between two recombination sites.

In MAT vector system transgene is placed adjacent to a multigenic element flanked by RS recombination sites. Selectable marker gene (ipt gene) from *A. tumefaciens* is inserted between these recombination sites together with yeast R recombinase gene. After transformation the MAT-vector system allows the removal of R recombinase gene along with ipt gene. Treatment with the herbicide antidote "Safener" is also used for the excision of recombinase and marker genes after the positive selection of transformed cells is achieved. Alternative method for the production of marker free transgenic *N.benthamiana* plants uses PVX-Cre and TMV-Cre recombinant viruses. In this method transgenic plants containing 10X sites and the bar SMG are inoculated with these recombinant virus

#### **Transposable Element Based System**

Transposable elements were discovered by Barbara McClintock in 1940. These heterologous plant transposons like AC and DS elements of maize have also been used for the removal of marker genes from the transgenic plants. AC transposable elements of maize were engineered to contain the ipt gene. As the transposable element encodes its own transposase and so it's excision remove this gene along with ipt marker gene. A MAT vector system containing the ipt gene and AC element has been designed so that when tobacco leaf segment were transformed and selected, excision of the modified AC produced marker free trans gene tobacco plants without sexual crosses and seed production. However there are several disadvantages of using a transposable elements system for marker gene removal. One of these limitations is genomic instability of transgenic plants because of continuous presence of heterologous transposons.

#### **Intra Chromosomal Recombination System**

Intra-chromosomal recombination system is an advanced approach used in the removal of selectable marker genes from transgenic plants. Like recombinase based system, there is no need of the recombinase expression in this system. The attachment site from phage origin is denoted POP (P for phage)

or attP and the attachment site from the bacterial origin "BOB" (B for bacteria) or attB. In order to remove the marker gene from GM plants it must be inserted between two direct repeats of attP so that its excision occurs spontaneously.

Zubko *et al* used pair of 352 bp attP region from Lambda phage as substrates for ICR in plants. The Lambda attP region recombines with the bacterial attB site during its integration into *E.coli*. Zubko *et al* also inserted a group of three marker and reporter genes in the construct used for plant transformation. In addition a transformation booster sequence (TBS) from *petunia hybrid* is inserted into the construct so that frequency of intra-chromosomal recombination and illegitimate recombinant events is increased in *petunia*, *Nicotiana* and *maize*. In this study *tobacco calli* were made marker free transgenic plants after their culture in Kanamycin containing media and kanamycin free media.

Siebert and patch used Uida (GUS) reporter gene in the double-stranded break repair mechanism which is turn led to the loss of a marker gene situated between the two rare restriction sites. The ICR method of marker gene removal is commonly used in both sexually and vegetatively propagated plants. However due to the involvement two-stage selecting procedure in transgenic cell, the risk of somaclonal mutation could be increased.

#### **Transformation by Marker Genes Not Based on Antibiotic Resistance or Herbicide Resistance**

In order to overcome the various limitations of selectable marker genes used in the genetic modification of plants, Scientists recently described marker genes of non-bacterial origin and marker genes from plants. *E.coli* derived phosphomannose isomerase (PMI) has been used as a selectable marker for transformation of many plant species such as Sugar-beet, maize, Wheat, Rice and Canola. However this system is not used in those plants that contain endogenous PMI.

Most recently *Aradopsis thaliana* ATP binding cassette (ABC) transporter (Atwbc19) gene is used in place of nptII gene as a marker. Other plant based marker are aspartate kinase and dihydrodipicolinate synthase (DHPS) genes for lysine inhibition are also used as a marker genes in transgenic plants.

#### **Application of GM Plants**

Genetic engineering has unlimited scope for application. The goal of plant genetic engineer is to improve the quality and yield of products.

Various important application of genetically modified plants are discussed below

#### **Insect Resistant Plants**

Through genetic engineering it is possible to develop crops that are resistant to insects and pests. One of the best example of this is the use of B.t genes in corn, cotton and other crops. Bt or *Bacillus thuringiensis*, is a naturally occurring bacterium that produce crystal proteins (Cry I, Cry II, Cry III, Cry 9C and others) that are lethal to insect larvae. B.t crystal protein's genes has been transferred into the corn to produce its own pesticides against insect such as earthworms (*Helicoverpa zea*). One of the most dangerous crop pest in North America. Also genetic researchers found a gene in the wild Mexican potato variety and engineered it into cultivated potato to make it

resistant to *phytophthora infestans*, the fungus responsible for Irish potato famine.

### **Virus Resistant Plants**

Several approaches have been used to engineer plant for virus resistance. One of these approaches involves use of coat protein gene.

GM plants having a virus coat protein gene linked to a stronger promoter have been produced in many plants such as tobacco, potato, papaya, yellow squash etc. The first transgenic plants of this type was tobacco produced in 1986. It contains the coat protein gene of Tobacco coat protein gene Mosaic Virus (TMV).

GE yellow squash termed freedom II was engineered with viral coat protein genes of two viruses watermelon Mosaic virus 2(WMV2) and Zucchini yellow Mosaic virus (ZYMV). Six varieties of GE yellow squash and Zucchini bearing various name e.g; Independence II, Liberator III, Freedom III and destiny III are also being produced. GE papaya is the only engineered fruit, which is commercially available was made resistant to papaya ring spot virus (PRSV) in Hawaii. Two GE varieties of Papaya like "Rainbow" and "sun-Up" was produced in 2006 and are cultivated in various countries. GE grapes (*Vitis vinifera*) were produced in the northern Alsace region of France in 2005 A coat protein gene from Fan-leaf virus was inserted into the grape root stock.

### **Herbicide Resistance Plants**

Herbicide tolerance is achieved through the introduction of a gene from a bacterium (*E.coli*, *Salmonella typhimurium*) conveying resistance to some herbicides. Many crops have been engineered for resistance to herbicides such as glyphosate (Roundup) and Phosphinothricin (the active ingredient of Basta). In situation where weed pressure is high, the use of such crops has resulted in a reduction in the quality of the herbicides used. Crops plants genetically- engineered to be resistant to one very powerful herbicides could help to prevent environmental damage by reducing the amount of herbicides needed. Monsanto has created a strain of Soyabeans genetically modified to be resistant to Glyphosate. A farmer grows these Soyabeans 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.

### **Development of Plant's Nutritional Content Like Aminoacid, Lipid, Vitamin and Iron**

The use of genetic engineering techniques allows scientists to develop the plants with improved nutritional quality. For example rice is extremely low in vitamin A. Scientists developed genetic engineering rice (Popularly known as golden rice), Which is enriched in pro-vitamin A by introducing three genes involved in the biosynthetic pathway of Carotenoids, the precursor for vitamin A. Since this rice was funded by the Rockefeller Foundation, a non-profit Organization, The Institute hopes to offer the golden rice seed free to any third world country that requests it. Stein *et al.* (2008) used representative household data from India to show that Golden rice could reduce the health costs of vitamin A deficiency by up to 60%. The first variety of Golden rice (GR1) contained three new genes, two from daffodil (*Narcissus*

*pseudonareissus*) and one from the bacterium (*Erwinia uredovora*).

Like vitamin A deficiency, Zinc and Iron deficiency is also a Global problem. Many programs have been instituted in order to treat these deficiencies. Researchers have inserted the human lactoferrin (major iron-binding protein) gene into the rice. Very high expression levels 5gm of lactoferrin/Kg of grain could be achieved. Another research group inserted the ferritin gene from *Phaseolus vulgaris* into the rice in order to double the iron content of dehusked rice.

### **Development of Drought Resistant and Cold Resistant Plants**

Plant tolerance to abiotic stress-such as drought, heat, salt is also being worked on intensively. Gallie's research team was able to use the tobacco's plant own genes to reduce the level of the enzyme dehydroascorbate reductase (DHAR) which reduces a plant's ability to recycle Vitamin C. As Vitamin C acts as an antioxidant, which destroys the oxidizers in plants such as hydrogen peroxide, whose increased level close the stomatal pores and that, in turn, signals the plant to slow the loss of water from its leaves. By reducing the Vitamin C level. Oxidizers remain high enough to keep the stomata closed. Creating plants that can withstand long periods of drought or high salt content in soil and ground water will help people to grow crops in formerly inhospitable places. An antifreeze gene from Arctic flounder was introduced into tomato in order to develop frost resistant plants. The gene used *afa3* encoded an antifreeze protein, which in the blood of polar fish was found to inhibit ice-recrystallization with this antifreeze gene these tomato plants are able to tolerate cold temperatures.

### **Plants as Bioreactor for the Production of Antibodies and Vaccines**

Transgenic Plants have been used to produce monoclonal antibodies and a number of potential therapeutic agents like human protein C (anti-coagulant), human erythropoietin (anemia), a potato based vaccine for hepatitis B, shown to raise immunological response in humans; a GE pollen vaccine that reduce allergy symptoms and an edible rice-based vaccine targeted at alleviating allergic diseases such as asthma, seasonal allergies and atopic dermatitis.

Plant vaccines have the advantage of being readily consumed with limited or no processing and of obviating the need for cold storage. Ventria, a Company that developed self-pollinating rice engineered to produce human lysozyme and lysozyme to shorten the duration of childhood diarrhea. These two substances treat the childhood diarrhea in a very short-time and also provides the patient with normal metabolic requirements.

### **Use of Transgenic Plant as an Alternative Source Of Energy**

The utilization of plants to produce alternative energy sources is a present focus of attention, given the global rise in non-renewable energy uses and greenhouse gas emissions. One approach involves engineering the green alga, *Chlamydomonas reinhardtii* to produce hydrogen gas, a clean, renewable fuel source.

GE bacteria engineered with trifunctional designer Cellulosomes or bifunctional system can degrade micro-crystalline cellulose and straw. Efforts are also aimed at

improving the ability of engineered plants and microbes to process Cellulosic biomass into usable biofuels.

### **Negative Impacts of GM Crops**

No doubt, genetic modification of the plants has the potential to revolutionize agriculture and to achieve long-term agricultural growth and food security. But many of the attitudes towards the use of GMOs in agriculture involve concerns about trust and perceived risk. Public perception of the use of genetic modification in food production is very emotionally charged. Environmental activists, religious organization, public interest groups, professional associations and other Scientists and government officials have all raised concerns about GM foods. The negative perceptions and fears about genetically modified foods worldwide are Considerable.

Most concerns about GM foods fall into three categories :-

1. Environmental Hazards
2. Human Health risks
3. Concern of legal issues associated with genetic engineering.

### **Environmental Hazards**

The negative impact of the GM crops on the environment and ecosystems is significant issue in the GM debate. A recent study found that caterpillars of the monarch butterfly (Which is not a pest species) that were forced under laboratory conditions to eat large quantities of the pollen from Bt maize (they would not normally eat pollen) suffered high mortality levels than caterpillars that were not fed the pollen. Although the Nature study was not conducted under natural field conditions, the results seemed to support this viewpoint. Unfortunately, B.t toxins kill many insect larvae indiscriminately; it is not possible to design a B.t toxin that would only kill crop damaging pests and remain harmless to all other insects.

Another concern is that crop plant engineered for herbicide tolerance and weeds will cross-breed, resulting in the transfer of the herbicides resistance gene from the crops into the weeds. There are fears that such transfer could facilitate the development of resistant "super-weeds" loss of genetic diversity within crop species or even the destabilization of entire ecosystems. Removal of weeds from all crops in the normal arable rotation would reduce the food supply for insects and birds. Thus genetic modification of the plants bring Unknown dangerous effects to the natural environmental gene flow by creating harmful superweeds, which threaten wild-life and biodiversity.

Cross-pollination of GM plants with non GM crops is another major concern. In the case of rape seed oil, researchers have found that its pollen can travel upto 4 kilometers and can escape from fields even when they are surrounded by barrier crops as a preventive measure. Due to this irreversible or uncontrollable "escape" of genes from a GM crop. The farmers find it difficult to produce non GM varieties. The negative GM contamination endanger the indigenous seeds that these farmers have developed over centuries and that they trust and know.

### **Human Health Risk**

At present, there is no evidence to suggest that GM foods are unsafe. However, there are no absolute guarantees, either.

Potential impact of GM crops on health including allergens, transfer of antibiotic resistance markers and 'outcrossing'. The movement of genes from GM plants into conventional crops or related species may have an indirect effect on food safety and food security.

The concern that a novel gene product may have the potential to include sensitization is legitimate; food allergy is not uncommon, the prevalence being in the order of 1-2 % in adults and even higher among in infants (Helm and Burks, 2000; Hourihanc, 1998) and a variety of plant proteins have been implicated as food allergens (Breiteneder and Ebner,2001; Bush and Hefle, 1996). The inducing allergen cross-links membrane bound IgE antibody, resulting in degranulation and the release of a variety of inflammatory mediators, including histamine, serotonin, chemotactic factors and prostaglandins. These factors cause allergic reaction. The most frequent symptoms of food allergy include nausea, vomiting, abdominal pain and Diarrhea. A recent National development of improved methods for identifying potential allergens, "superficially focusing on new tests relevant to the human immune system and on more reliable animal models.

Genetically engineered foods may also carry an antibiotic resistant gene and one commentator has argued that, "some of the antibiotics used for this purpose are still used to treat human illnesses, and there is concern that resistance to the antibiotics could be transferred to humans and animals through food and feed products. Foreign genes introduced into food plants may therefore carry potentially harmful substances that may have negative impacts on human health.

### **Concern of Legal Issue Associated With GM Crops**

Farmers with contaminated field could also end-up being forced to pay royalties to the companies that own the patents on the GM crops that contaminated their fields. This introduces the concern of legal issues associated with genetic engineering. GM foods are a product of human intellectual efforts, and Intellectual property.

The Proliferation of IPRs on genes, processes and technologies has led to access and freedom to operate problems within the Biotechnologies industry. Intellectual property rights creat monopoly in organisms, and the access to GM technology become limited by restrictions. Legal actions can be pursued against those who infringe upon the patent. Patented corps are significantly more expensive than conventional or hybrid crops. When GM seed prices are too high, resource poor farmer face access problems (Qaim & de Janvry). Also farmers that use GM seeds have to contract with the seed company not to grow the seeds they harvest. This would reduce the range of native seeds. Therefore it is claimed that GM crops are immoral because, as we have seen they threaten the traditional rights of farmers by denying their ability to save the seeds of their harvests. All these issues are largely legal rather than biological in nature and revolve around the Intellectual Property rights.

### **Safety Assessment of Genetically Engineered Crops**

The application of biotechnology in the genetically modified food industry has raised a lot of questions and criticisms despite the idea that this technology will help to produce better foods and even someday would solve the world's hunger problem (James 2010). Many believe that if we want to

improve public perception towards this technology, information sharing process must be properly made. Lack of Knowledge will only hamper biotechnology development and cause misperceptions on its application (Gaskell *et al.* 2004).

The starting point for the safety assesment of genetically engineered food products is to assess if the food is substantially equivalent to its natural counterpart. In deciding whether a modified product is substantially equivalent, the product is tested by the manufacturer for Unexpected changes in a limited set of components such as toxins, nutrients or allergens that are present in the unmodified food. The data is then assessed by an independent regulatory body if these testes show no significant difference between the modified and unmodified products, then no further food safety testing is required.

In India regulation of genetically engineered crops is extremely important to address the biosafety concerns associated with these products. The concept of food safety assurance has assumed importance as with any method of Genetic modification, there is a possibility of introducing unintended genes Which is turn have an impact on the health and nutritional status of the consumer. The international food code or the Codex Alimentarius has been used as a point of reference. The Government of India stresses its focus upon the following factors of GM crops. These factors taken into account in the safety assesment and include Identity, source, Composition. Effects of processing/Cooking, Transformation process, the Recombinant DNA (e.g. stability of insertion, potential for gene tranfer, Expression product of the novel DNA, potential intake and dietary impact of the introduction of the GM food. When transgene has been declared biosafe its derivatives need not always be evaluated for biosafety to the same extent again.

Most, if not all of GM crops contain compounds that are potentially toxic or allergic. In order to avoid these problems, public requires a higher level of assesment of the safety of GM food. The first structured approach to allergy safety assesment resulted from a collaboration between the International Food Biotechnology Council (IFBC) and the International Life Science (ILSI) Allergy and Immunology Institute. In these approach the route taken was dictated by whether or not the protein of interest derived from a source that has previously been associated with allergic disease in humans (Metcalf *et al.*, 1996). Using this approach, the assesment of potential allergenicity is based on an evaluation of the ability of the test material to provoke an IgE antibody response.

With this safety assesment approach and also by other national and International biosafety measures, the risk and hazards of the GM crops and foods are taken into the consideration. Not only for the human health, but also for the other animals and environment these biosafety measures play a vital role in their maintenance by avoiding the negative impacts of GM technology. Safety assesment programms regulate GMO dealings in a way that will relieve public health and safety concerns

### ***The Release of Genetically Modified Crops Into The Environment***

Three quarters of GM crops which are grown worldwide are cultivated in develop countries predominantlly on large scale

industrial farms in the US, Argentina, and Canada. Traits which have been successfully introduced by means of genetic modification relate primarily to the needs of these farmers. The area Worldwide in which GM crops are grown and tested exceeded 50 million ha in 2001 (James, 2001). Despite the potential benefits of the GM plants, the intensive agriculture also adversely affects the environment, because farmers are using herbicide resistant plants, which not only destroys harmful insects but also kill other harmless organisms. The effects of GM crops have about to be measured against the effects of agriculture in general.

### ***Current Status of GM Crops In The Environment Around The Globe***

The international Service for the Acquisition of Agri-Biotech Applications (ISAAA) maintains an up-to-date database on the global areas of commercial major foods. In 1996, only 1.7 million ha of GM Crops were planted in six countries: USA, China, Canada, Argentina, Australia and Mexico. By the end of 2001, the total area dedicated to GM crops increased to 52.6 million ha and the number of countries growing these crops has more than doubled (James, 2001).

Over 98 % of all GM crops in developing Countries are grown in Argentina and China. China has approved 31 application for Commercialisation of GM Crops (Huang *et al.*, 2002). On a global bias, GM crops are grown by an estimated 5.5 million farmers. Over 5 million (90 %) of these are resource poor farmers, mainly growing GM Cotton in China and South Africa (James 2001, 20002). Biosafety assesment of GM crops that have received regulatory approval for Commercial release is maintained by Agriculture and Biotechnology strategies Inc. (AGBIOS). In 1996, the main GM crops grown Commercially was virus resistant tobacco in China, followed by Cotton, Soyabean, Maize, Oilseed rape, tomato and potato. From 1997 on, GM HR Soyabean has been the dominant GM Crop. In 2001, the area of GM HR Soyabean reached 33.3 million ha, Which is 63 % of the total area of GM Crops worldwide.

GM maize occupied 9.8 million ha in 2001 (18 %) other GM crops are GM cotton (6.8 million ha, 14 %) and oilseed rape (2.7 million ha, 50 %). Before the Commercialization, GM Crops are tested in field trails. The Biosafety Information Network and Advisory Service (BINAS) of the United Nation Industrial Development Organization (UNIDO) maintains a database of field trails around the World. This database is partly linked with the Biotrack database (<http://www.olis.Oeed.org/biotrack.nsf>) of the organization for Economic Co-operation and development (OECD).

The OECD database currently records over 10300 permits, 98.4 % of which Concern GM plants. The first experimental field tests took place in 1986. The total number of approval in the OECD member states has been rapidly rising to reach a peak of 2312 permits issued in 1998. China, may well have the largest plant Biotechnology capacity outside the USA (Huang *et al.* 2002). Field release comprise numerous GM Crops such as rice, tobacco, potato, Tomato, maize, Soyabean, Orange, oilseed rape). In other countries like Philippins, Egypt, Kenya, Zimbabwe, Russia etc. field trails of GM Crops have been conducted on the various traits.

The legislative and regulatory authorities of the release of GM Crops around the globe helps in ensuring safe and effective evaluation of the impact of GM Crops. North America and Europe have paved the way for the development and environmental release of GM Crops. They have also defined the general framework for a regulatory system. Several organizations are instrumental in helping countries to generate the capacity for evaluation of the impact of GM crops. Among these there are International Service for National Agriculture Research (ISNAR) of the Consultative Group on International Agriculture Research (CGIAR), e.g. Cohen, 1999; McLean *et al.* 2002; Persley *et al.*, 1993). The ICGEB; and the United Nations Environmental Programme (<http://www.unep.ch/biosafety>). UNEP issued International technical guidelines for safety in Biotechnology in 1995 (UNEP, 1995). A UNEP-Global Environment Facility (GEF) project on the development of National Biosafety Frameworks is designed to assist countries to develop their National Biosafety Frameworks.

In USA, a recent National Academy of Science Evaluation, of current US regulation (NAS, 2002) suggested monitoring of the environmental release of all crops including those resulting from traditional breeding (Gewin, 2002). In Argentina CONABIA is a multi-disciplinary advisory group that is responsible for the regulation of products of agricultural biotechnology. It evaluates the issues of environmental release of GM crops and makes recommendations to the secretary of Agriculture who makes the final decision. In Canada, the plant Biosafety office (PBO) of the Canada Food Inspection Agency (CFIA) monitors all field trials of novel crop varieties to ensure that the trials comply with the guidelines for the environmental release (Regulatory Directive 2000-07; amended February 2002).

China has implemented a very pragmatic approach to GM crops regulations. The state Science and Technology Commission drafted a "Regulation on Biosafety Control of Genetic Engineering" that established the legal framework for the release of GM crops. In Australia, from June 2001 new gene technology regulatory regime is governed by the gene technology Act (GTA), which regulates all dealings (e.g.; research, manufacture, production and importation) with organisms that have been modified by gene technology (Mackenzil, 2000).

Various Asian countries are in the process of establishing their legislative framework for environmental and commercial release of GM Crops. India has established a Genetic Engineering Approval Committee (GEAC) to oversee GM Crop applications. Currently, 26 Asian and Pacific countries participate in the UNEP-GEF Project (UNEP-2002). All these regulatory authorities in the various countries require the documentation of similar information when considering application for the release of GM Crops.

#### **Status of GM crops in India**

Like other countries, India has been carried out experiments on GM crops like Golden rice (which is rich in proteins). India is the third largest producer of cotton after China and the U.S. The Maharashtra Hybrid Seed Co. Ltd Mahyco is one of the largest and most trusted seed companies in India. In 1998 Monsanto became a 50% share holder in the company.

In June 2002, about 55000 cotton farmers decided to grow Bt cotton. In the first few months, the farmers were delighted with the crop but unfortunately, in the fourth month there was heavy infestation of bollworm. The Bt cotton failure has cost the farming industry a total loss of Rs. 1128 million or 20 million euro in 105000 acres across the country in one cropping season. Monsanto claimed that the crop would be resistant to the bollworm provided that there was a 20% refuge crop of non-BT cotton planted alongside the BT 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 the immunity to the BT toxin. On the 5<sup>th</sup> 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 is called, was unveiled at the Indian science congress.

India is fast turning into a dustbin for the new technology. India has meanwhile become a favoured destination for the biotechnology industry that is virtually on the run from the US, EU and Australia. In India, besides cotton, genetic engineering experiments are being conducted on maize, mustard, sugarcane, sorghum, chickpea, rice, tomato, potato, brinjal, papaya, cauliflower, soybean 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 it is desirable or not. The mad race for GM experiments in the outcome of more findings 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 GM 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.

#### **Economics of Genetically Modified Plants**

Genetically Modified plants involve improvements in Agronomic traits, quality traits and some plants are also designed to produce Pharmaceutical substances and some Industrial materials. These Potential of GM Crops are manifold and play an important role for rural income growth and poverty alleviation in developing countries (Hozall and Ramasay, 1991, Fan *et al.* 2005). Nutritionally enhanced crops could help improve the health status of consumers (Bouis 2007, Unnevehr *et al.*, 2007). In spite of these potentials there are also fears about adverse social implications (Altieri 2001, Friends of the Earth 2008).

GM technology also increases privatization of Crop improvement research and proliferation of Intellectual Property rights (IPR). In 2008, GM Crops. Economic estimates, Economic analysis with different model specifications confirm the net insecticide reducing and yield increasing effects of Bt technology. In all countries Bt-adopting farmers benefit; that is

the economic advantages associated with insecticide savings and higher effective yields more than outweigh the technology fee charged on GM seeds. GM crops may also have important implication for poverty and income distribution in developing Countries. Several studies show that Bt technology advantages for small scale farmers are of a similar magnitude as those of large scale producers. In some cases, the advantages can be even greater (Pray *et al* 2001, Morse *et al* 2004, Qaim *et al*,2008).

GM Crops can contribute significantly to poverty reduction and rural development. When they are suited to the small farm sector and embedded in a conducive institutional environment. Most GM technologies currently available have been Commercialized by the Private sector, technology rents accrued by innovating Companies need to be considered (Moschini and Lapan 1997). Price *et.al* (2003) estimated that in the late 1990, Bt cotton generated a total annual economic surplus gain of approximately \$.164 million in the United states of which 37% was captured by farmers, 18% by consumers and 45% by the innovating Companies.

Bt maize in the US, will estimated a total surplus gain of \$ 334 million in 2001. Approximately half of the gain accrued to producers followed by industry profit (31%). These studies confirm that GM Crops can bring about sizeable welfare gains, with distributional effects dependent on IPRs and other Institutional Conditions. In the general equilibrium approaches Bt cotton adoption entails global welfare gains in the range of \$ 0.7-1.8 billion per year. Larger International markets result in bigger effects for Gm oilseeds and maize with wide spread International adoption of HT and insect resistance in these Crops, annual welfare gains could be approximately \$10 billion (Nielsen and anderson 2001).

Wide spread production and consumption of biofortified staple crops could reduce micronutrient deficiencies, improve health outcomes and Provide economic benefits (Bouis 2007). Dawe *et al* (2002) look at the potential nutritional effects of Golden rice by analyzing likely improvements in Vitamin A intakes in Philipins. Significant economic and health benefits can also be expected for other biofortified crops such as iron and Zinc dense stable foods or crops containig higher amounts of essential aminoacids (Qaim *et al* 2007). However possible issues of consumer acceptances must be considerd. Especially when no price premium is paid in the output market, suitable strategies to Convince farmers to adopt such crops are needed. Aspects of GM Crops accepstance have been widely analyzed in the literature of economic related to GM plants. The first approach involves choice modeling or Contingent valuation surveys to obtain stated preferences data from consumers. Introducing GM technology would be associated with a negative point, which would need to be accounted for in welfare economics studies (Giannakas an Fulton 2002, Lapan and Moschini 2004). There are also indication that consumers in developing Countries have more positive attitudes towards GM food than their Counterparts in developed Countries (Kimenju and De Groote 2008, Krishna and Quain 2008).

The development of GM technologies leads to public goods that can easily be reproduced, so IPR protection is needed as an incentive for private sector R and D investments. New laws and Institutions to regulate potential biosafety and food safety

issues have been established, requiring that GM products be approved before they may be grown in consumed in, or imported into the country. some reform of the GM regulatory framework will be necessary and economists have an important role in this respect in terms of quantifying costs and benefits.

Labeling an Cexistence of GM Crops are also related to the economics of these crops. Labeling involves market segregation and a system to identity preservation, Which can be quite costly Giannakas and Fulton (2002) and Lence and Hayer (2005) showed that labeling in general and segregation crops in particular can influence the welfare effects of GM crops significantly. Intellectual property Rights and public Private partnership issues of GM Plants enhance the costs of GM proucts. Nowadays more than 75% of all patents in agricultural biotechnology are held by private sector, mostly by a few large multinational Corporations. The Proliferation of IPRs on genes. Processes and technology has led to access and freedom to operate problems within the biotechnology Industry. More public private partnership should be sought to harness the Comparative strength of both sectors (Rausser *et al*.2000, Byerlee and Fischer 2002).

Economic research has an important role to play in finding ways to maximize the net social benefits.

## **CONCLUSION**

Researchers using Genetic engineering process modify many of the important crops by the introduction of desired gene from other plant species or from any other organisms. This technology opens the door to changing agricultural crops in ways not previously possible. These changes or modification of the crops can result in plants that are better able to survive pest attack and draught stresses. various beneficial products are also produced from the plants by genetic manipulation such as antibodies, vaccines which in turn are used as pharmaceutical substances. Most of the GM crops employed have been HT and insect resistant. During genetic modification some type of markers are used for identification of transgenes. Now a days the field of marker gene removal continues to product new innovations. Serveral methods for the removal of unwanted marker genes already exist. The techniques for marker gene removal under development will also facilitate the more precise and suitable engineering of the plant genome with widespread application in biotechnology.

Despite the safeguards applied to GM Crops and foods and the clear benefits that they are bringing, public acceptances is currently low. There are several reasons for this including allergenicity, environmental risk and so, with the proper balance of caution and scrutiny, we can take advantage of the power of this technology without Compromising the health of humans,animals or the environment. To achieve that proper balance it is important to know the facts about the technology and its products. The ongoing globalisation of agriculture prouction and the increased role of GM crops in the production puts pressure on the global harmonisation of regulation and legislation of GM crops. More work is needed to quantify possible indirect effects of GM crops, including socio-economic outcomes. Economists need to contribute to the design of efficient regulation an innovation systems in light of changing framework conditions. Scientists also examine the transgenic Organisms for the safety of consumers and farmers.

Government authorities and other national and International agencies associated with the safety assesment of GM Crops would evaluate appropriate models that are able to inform the safety assesment process. 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 benefits. However we must proceed with caution to avoid risks to human health and the environment.

### Summary points

- GM crops involve improvement in agronomic traits, enhance quality traits such as higher nutrient contents of food products.
- Pharmaceutical substances like antibodies vaccines and other industrial substances are also produced from GM crops.
- Gene transfer strategies include Agrobacterium mediated transformation, direct gene transfer by particle bombardment, microinjection and electroporation methods.
- Marker free transgenes are produced in order to avoid the horizontal tranfer of antibiotic resistance genes from plants to the human beings and animals
- In spite of the various advantages and benefits of the GM crops, there are also negative imacts of biotechnology on environment and human health. So concerns about various risks have led to complex and costly biosafety.
- India, becoming a dumping gound of GM Crops, practized the GM technologies very fastly without proper assessing of GM foods.
- Bt crops can also be suitable for small scale farmesrs. Evidence from India and other developing Countries shows that they contribute to higher household incomes and poverty reduction, when embeded in a conducive Institutional environment

### Future Issues

The types of GM crops that may become available in the future could boast crop yield while enhancing the nutritional value of the staple foods and eliminating the need for inputs that could be harmful to the environment. But the environmental health and economic risks of GM crops should be carefully studied before full scale adoption. Also, agricultural biotechnology must be made affordable to the developing world farmers. Introduction of Pharmaceutical and industrial proteins into edible genetically engineered crops raises issues that require additional safety and regulatory scrutiny.

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