Dilemma with Genetically Modified Crops in India: A Review

Brajesh Kumar Mishra[1*], Prajjwal Rai[2], Jitendra Ojha[3], Udai Bhan Singh[4], Krishna Kumar Mishra[5], Aneeta Yadav[6],

[2]*Institute of Agricultural Sciences, (Rajiv Gandhi South Campus), Banaras Hindu University, Barkachha, (Mirzapur)-231001, U.P., India.*

[1, 3, 4, 5, 6] *Faculty of Agricultural Sciences and Allied Industries*

Rama University, Rama City, G. T. Road, Kanpur-209217, U.P., India.

**Corresponding Author: brajeshmishraphd@gmail.com*

Abstract

With the ever rising world population and decreasing arable land, there is an uncertainty surrounding food and nutritional security. The criterion of selectivity and desirability present in conventional breeding gave rise to the concept of genetic modification, which is the alteration of genome of an organism by inserting gene of others. The Recombinant DNA technology is the underlying principle of this. As of 2016, the area under biotech crops is 5.3 billion acres. The main steps involved are isolation and insertion of gene, selection, regeneration and verification followed by assessment of plant performance and safety. The 4 basic types of modification are transgenic, cisgenic, subgenic and multiple integration. PCR is used for the detection of GMOs. Both quantitative and qualitative approaches are used for their detection. The GM crops are produced for different traits such as extended shelf life and disease resistance. In India, Bt Cotton is the only transgenic crop in the market, while Bt Brinjal and GM Mustard are waiting in line. With certain advantages of the GM crops, many issues are also there to be addressed but only through proper assessment and scientific approach.

Key Words: genetic modification, Recombinant DNA Technology, transgenic, cisgenic, subgenic, PCR (Polymerase Chain Reaction), Bt (*Bacillus thuringiensis*).

Introduction

Genetically modified organism (GMO) is defined as the organisms whose genetic makeup has been altered by transferring of genetic material from another organism in a controlled manner. This alteration does not occur by random mating or the natural recombination. The technology involved is known as 'Recombinant DNA Technology'. It also enables to transfer the genetic material between two unrelated species for e.g. The Bt gene from bacterium Bacillus thuringiensis to the Cotton plant, thus imparting the name Bt Cotton. The technology has served great human purpose, as the mass production of GM technology based growth hormones, drugs and the insulin has opened the door for more inclusive health care by increasing the reach of these pharmaceuticals.

Genetically modified crops also known as the biotech crops are the plants that are agriculturally used, having a modified DNA for a particular trait using the GM technology. It creates a desired change by simply adding, deleting or manipulating the genome of an organism to create a desired change.

The history of genetic modification is a very long one as it does not only include the laboratory-based ones, but also those which were prevalent in ancient days. The transition of humans from a hunter-gatherer to a cultivator happened around 10,000 years ago and continued till the modern days **(Diamond *et al.*, 1997).** Domestication happened through Selective breeding. The organisms with desired traits were carried forward in the breeding activity, while undesired plants were left out. This criterion of selectivity and desirability gave rise to the concept of genetic modification **(Zohary *et al.*, 2012).** In 1983, an antibiotic-resistant tobacco plant was used to produce the first genetically modified crop **(A. Kumar and Bawa, 2016)**. In 1988, the US Food and Drug Administration approved the use of genetically modified microbial enzyme for the first time, thus opening the doors for use of GM crops for other than direct consumption purposes **(Annonimus, 1999)**. The Cheese was made by enzyme complex Rennet that was extracted from the inner linings of cow stomach. The bacteria modified by the scientists, was able to produce chymosin and clot the milk thus enabling cheese formation **(Geoffrey, 2011)**. In 1994, Calgene developed the Flavr Savr tomato that had an antisense gene that increased its shelf life and delayed ripening **(Clive, 1996; Bruening and Lyons, 2000)**. In 1994, the bromoxynil resistant tobacco was approved by the EU making it the first marketed GM in Europe. In 1995, Bt maize developed by Ciba-Geigy, bromoxynil resistant cotton by Calgene, Bt cotton and glyphosate resistant soybeans by Monsanto, Asgrow developed a virus resistant squash and additional delayed ripening tomatoes by the DNAP, Zeneca/Peto, and Monsanto were approved and subsequently found a place in market. The first pesticide producing crop to be approved in US was the Bt Potato in 1995 **(Ammoniums, 1995)**. The nutritional aspect of the crop had its due modification when the scientists developed Golden Rice enriched with Vitamin A in the year 2000 **(Xudong *et al.*, 2014)**. In 2013, Robert Fraley, Marc Van Montagu and MaryDell Chilton were awarded the World Food Prize for improving the "quality, quantity or availability" of food in the world. In April 2016, CRISPR technology was used to develop a white button mushroom (*Agaricus bisporus*) **(Emily, 2016)**.

Area, Distribution and Economic Benefits of GM crops

In 2016, the accumulated area planted since 1996 under the biotech crops increased up to 2.1 billion hectares or 5.3 billion acres (Table 1). Total 26 countries planted the biotech crops in 2016, out of which 7 were developed or industrial countries and 19 of them were developing. If the global area of biotech crops is put into context, it is equivalent to the 20% of land area of China (956 million hectare) or the US (937 million hectare). It is also equal to 7 times the land area of United Kingdom (24.4 million hectares). Nearly 13.3 million acres of area was increased in just 1 year (2015 to 2016), which is 3% of total area of biotech crops.

There has also been a continuous changing trend of the developing countries catching up with the developed in terms of the area under biotech crops. Prior to 2011, the developed countries had a larger share of area but it reached to equality in 2011; and for the past 6 years, the developing countries are beating them every year(since 2012) **(Table 2) (Ammoniums, 2016)**.

Table 1: Global Area of Biotech Crops, the First 21 Years, 1996 to 2016.

Year	Hectares (million)	Acres (million)
1996	1.7	4.2
1997	11.0	27.2
1998	27.8	68.7
1999	39.9	98.6
2000	44.2	109.2
2001	52.6	130.0
2002	58.7	145.0
2003	67.7	167.3
2004	81.0	200.2
2005	90.0	222.4
2006	102.0	252.0
2007	114.3	282.4
2008	125.0	308.9
2009	134.0	331.1
2010	148.0	365.7
2011	160.0	395.4
2012	170.3	420.8
2013	175.2	432.9
2014	181.5	448.5
2015	179.7	444.0
2016	185.1	457.4
Total	2,149.7	5,312.0

Global hectarage of biotech crops in 2016 increased to 185.1 million hectares compared with 179.7 million hectares in 2016, equivalent to 3% or 5.4 million hectares.

Source: ISAAA, 2016.

Table 2: Global Area of Biotech Crops, 2015 and 2016: Industrial and Developing Countries (Million Hectares).

Countries	2015	%	2016	%	+/-	%
Industrial Countries	82.6	46	85.5	46	+2.9	+3.5
Developing Countries	97.1	54	99.6	54	+2.5	+2.6
Total	179.7	100	185.1	100	+5.4	+3.0

Source: ISAAA, 2016

Regarding the economic benefits harvested through GM crops, nearly US$167.8 billion was the additional income garnered by the framer in nearly 20 years (1996-2015). Nearly US$86.1 billion was generated in the developed nations and US$86.1 in developing. The developing countries had a slightly lower share as compared to the developed ones (48.75%) regarding the total gains. The six countries which are the major benefiters of biotech crops are in descending order, the USA (US$73 billion), Argentina (US$21.1 billion), India (US$19.6 billion), China (US$18.6 billion), Brazil (US$16.4 billion) and Canada (US$7.3 billion). The total benefits were US$15.4 billion out of which US$7.9 billion was for the developed and US$7.5 billion for the developing nations (2015) **(Ammoniums, 2017)**. It has also been concluded that the GM technology has helped to reduce pesticide inputs by 37%, farmers' profits by 68% and the crop yield was increased up to 22% (Clive James, 2014). The yields and profits generated by the GM crops are more in developing countries than in the developed countries.

Development of GM Crops

The genetic modification in an organism is a multi-step procedure in which following steps are involved:

1. **Isolation of the gene of interest:** Identification of gene is facilitated by the knowledge of structure, function and the location of chromosome for e.g. disease resistance in a plant. Detailed information about the characteristics of the gene of interest is provided by the developer. It clearly defines the function of the particular gene in donor organism and that in the recipient organism as well. It should also keep in mind the adverse impact that the foreign gene can cause in the recipient organism or plants (in the GM crop case).
2. **Insertion of the gene into a transfer vector and plant transformation:** Agrobacterium tumefaciens is the most commonly used gene transfer tool for plants. The circular DNA (plasmid) is used for this purpose. Recombinant technology is used to insert the gene into plasmid. The bacterium is a natural plant parasite **(Halford and Nigel, 2012)**. These Agrobacteria create a suitable environment for themselves by inserting their gene into the plant host. It also results in proliferation of modified plant cell near soil level (crown gall). The plasmid carries the information for genetic transformation. The TDNA is transferred to the plant genome after the infection and in genetic engineering the TDNA is removed and replaced with a desired foreign gene. It is a well suited method for potato, tomato and tobacco. It is found to be less successful in the case of wheat and maize. Another well used method is the Gene Gun also known as Biolistics. They shoot high energy particles for the transferring of genetic material. Tiny particles of Gold and Tungsten are used to bind the DNA and high pressure shooting into the plant cell or tissue. The cell wall and membranes are penetrated by the accelerated particles. The DNA separates from the metal and is incorporated into the host nucleus. It is a successful method in case of wheat and maize but severe damage is reported in this method **(Shrawat and Lörz, 2006)**. A new technique has been evolved for the transferring purpose known as Clustered regulatory interspaced short palindromic repeats (CRISPR) which involves segments of prokaryotic DNA having short, repetitive base sequences. Each repetition precedes short segments of spacer DNA from previous exposure to foreign DNA. It is also known as Cas system. TALENS (Transcription activator-like effecter nucleases) are artificial restriction enzymes that are prepared by fusing Tal effecter DNA- binding domain to a DNA cleavage domain. DNA strands are cut at specific sites by this Restriction enzyme **(Gaj *et al.,* 2013)**. Electroporation can also be used when the plants do not contain cell wall. Miniature pores are formed due to electric pulses and the DNA enters through these pores. Foreign DNA is directly injected into the cells by the technique of Microinjection **(Maghari and Ali, 2011)**. It is also contested that the GM technology provides more target based changes than the conventional breeding programme **(Catchpole *et al.,* 2005)**.
3. **Selection and Regeneration of the modified plant cells into whole plants:** Even after successful transformation, a very low number of plant cells take up the gene of interest and most often, the growth of the transformed cells as compared to the non-transformed cells is conferred by the selectable marker genes. The genes that are responsible for resistance are inserted into the vector and transferred along with genes of desired traits. The result of this transformation is positive as when they are exposed to the herbicide or antibiotic, only the transformed cells with selectable marker gene survive. Tissue Culture is then used to regenerate the cells into whole plant. The information about the marker genes and their presence is provided to the regulators as well. In the whole process, the regulators must be informed about the genes of interest, promoter, marker gene, vectors and transformation method; by the developer.
4. **Verification of transformation and characterization of the inserted DNA fragment:** verification is the most crucial step of the whole process. This is the demonstration of the gene and its insertion and inheritance normally. There are numerous tests conducted for the determination of number of copies inserted, whether these copies are intact, and regarding the insertion not interfering with other genes to cause an unintended effect. The gene expression is also checked and the trait is evaluated and made sure that the gene is functional in the host.
5. **Testing of Plant Performance:** Repetitive trials are used to test the plant's performance in field conditions. It is done to assure that the gene of interest has been consolidated in the plant and is able to express itself in further progenies. If the gene is able to express itself, it is notified as a new plant variety.

6. **Assessment of safety:** Testing of plant performance is carried out in conjunction with the food and environmental safety assessment. Various countries have different food and Environment safety related acts and laws and the Gm crops have to comply with those laws.

Types of Modification

There are 4 types of modification in a GM crop. First of them is the Transgenic. The genes derived from other plants, when inserted into a plant; it is called as transgenic plant. It can be from the same kingdom (plant to plant) or between different kingdoms (bacteria to plant). The inserted DNA has to be modified in most of the cases to ensure effective expression. The transgenic plants are used to express different proteins like the Cry protein from *Bacillus thuringiensis*, antibodies and the antigens for vaccines **(Walmsley and Arntzen, 2000)**. Cisgenic plants are produced using genes of same or closely related species in which the conventional plant breeding can occur. There is a strong contention that conventional breeding is difficult to achieve in the cisgenic plants but the regulatory scrutiny is very less as compared to the transgenic ones **(MacKenzie, 2008)**. Gene knockout or Gene knockdown can also be used to alter the genome of a plant without inserting genes from other organisms or plants. In 2014, Chinese researcher Gao Caixia used the TALENs and CRISPR gene editing tools without alterations in the genome. It lacked immediate field trials **(Wang, 2014)**. And the last technique is the Multiple Integration, through which several new traits may be integrated into a new crop and can be further used **(Sun and Mumm, 2015)**.

Detection of genetically Modified Crops

The detection of genetically modified crops is necessary as it enables proper labeling of the product and helps consumer to know what he is consuming. It is possible by the biochemical means. It can be qualitative (which GMO is present) or quantitative (the amount of GMOs present).

Polymerase Chain Reaction: The PCR is a biochemical technique for isolating and exponentially amplifying a fragment of DNA by the enzymatic replication without any living organism. It is photocopied at an exponential rate. The targeted genetic sequence is paired with Primers (custom designed complementary bits of DNA). The primers trigger a chain reaction after matching with it in the presence of target sequence. After that the DNA replication enzyme starts doubling the target sequences. Sequential heating and cooling are followed by multiplication up to a million-fold times. The millions of identical fragments are then purified in a slab of gel. It is later on dyed and can be seen through a UV light. Several elements of the DNA of GMO govern its functioning. They are promoter sequence, structural sequence and the stop sequence for the particular gene **(Schreiber, 2005)**.

Qualitative Detection: The presence or absence of GMO is analyzed by Q-PCR or Multiplex PCR. Multiplex PCR uses multiple, unique primer to produce amplifications of various sizes that are specific to different transgenes. The Annealing temperatures must be optimized for each primer sets in order to work correctly within a single reaction. The Amplicon sizes should also be able to form distinct bands when they are visualized under Gel Electrophoresis.

Quantitative Detection: It is used to measure the quantity of any PCR product **(Logan *et al.*, 2009)**. Q-PCR is used to determine the presence of DNA sequence and number of its copies in a given sample. The QRT-PCR use fluorescent dyes or fluorophore containing DNA probes, such as the TaqMan for the measurement of amplified product in real time.

Event-Specific vs Construct-Specific: When there is a test conducted for the unintended presence of GMOs, it is very difficult to comprehend the type of GMOs. The US administration prefers a Construct-specific approach while the EU authorities have an Event-specific outlook to this case. The event-specific approach searches for the DNA sequence in the junction of organism's original DNA and the transgene. This is ideal for the GMO identification but similar GMOs can pass being unnoticed. It is a PCR based approach. The construct –specific detection is either DNA or protein based. The foreign DNA inserted in a GMO is probed by the DNA based detection. Several GMOs contain certain DNA sequences. The protein based methods detect the product of transgene. The counter-specific is able to test several GMOs in a single step but cannot tell about the similar types of GMOs present.

Shortcomings of current detection methods: The main problem with the current detection methods is that it is very difficult to analyze the presence of unknown GMOs as the sequence of the transgene must be known for this purpose. It is time consuming and costly and the current methods are able to test only one GMO at a single time. So, alternative methods such as the DNA microarrays are developed. Some of the alternative methods are Improving PCR based Detection, Detecting unknown GMOs and The Near infrared fluorescence (NIR).

Traits for which GM Crops are developed:
The GM crops that are grown today are developed for various traits that are economically viable for the production and consumption purposes. The traits for which they are developed are disease resistance, shelf life, stress, herbicide and pest resistance, production of useful secondary goods such as the Biofuel or drugs and bioremediation of pollution by absorbing toxins. Recently the approach has shifted to the enhancement of crops that are important in the developing world such as insect resistance in Brinjal and Cotton **(http//www.isaaa.org)** and insect resistance cowpea in the African continent **(http//www.seedquest)**.
Extended shelf life: FlavrSavr tomato was the first genetically modified crop approved in the United States. It was developed for extended shelf life. It was first sold in 1994 but ceased in 1997 **(Weasel *et al.*, 2009)**. The GM potato was approved in the US in November 2014 that prevented bruising **(Andrew Pollack, 2014)**. The Arctic Apples approved by USDA **(30)**, became the first GM apple in US. It reduced the expression of Polyphenol Oxidase (PPO), thus preventing the browning of fruit after slicing. This trait was added to Golden Delicious and Granny Smith varieties **(Anonymous, 2013)**.

Improved Photosynthesis: Plants use non-photochemical quenching (NPQ) for the protection against excessive amount of sunlight. They can switch on instantly but switching off takes a longer time. During the switched-off period, the amount of wasted energy increases. Genetic modifications can correct this and nearly 14-20% rise in the weight of dry leaves is registered. The plants had bigger leaves, were taller and more profound roots were also present. Photorespiration is another evil responsible for the loss of yield in C3 plants. By inserting the C4 pathway into C3 plants, productivity of cereal crops increase by 50% **(Karki *et al.*, 2013)**.

Improved Nutritional value: **Edible Oils:** The oil profile can be improved by the GM Soybeans **(34)**. *Camelina sativa* is used to produce oil that is somewhat similar to the fish oil **(Sayre *et al.*, 2011)**.

Vitamin enrichment: The International Rice Research Institute (IRRI) developed Golden Rice that provided greater amount of Vitamin A to reduce its deficiency in the developing countries. But still, as of January 2016, it is not grown commercially anywhere in the world **(Paarlburg, 2014).**

Toxin Reduction: A genetically modified Cassava under development offers enhanced protein and other nutrients (BioCassava) and relatively lower cyanogens glucosides **(Sayre, *et al.*, 2011)**.

Stress Resistance: The biotic and abiotic stresses are the major hindrances for raising the production. It is very difficult to create tolerance for theses stresses by conventional plant breeding. So, the GM crops offer a smart solution to counter these problems. Plants are engineered to tolerate drought and high soil salinity **(Banjara *et al.*, 2012)**. In the year 2011, Monsanto's Drought Gard Maize became the first drought resistant crop to get the approval of USDA and subsequently the market approval **(Carpenter and Gianessi, 1999)**. The drought resistance occurs by modifying the plant's genes responsible for the Crassulacean Acid Metabolism (CAM) mechanism that allows the plants to survive in low water conditions. It can prove to be instrumental in growing water-heavy crops such as rice, soybean and wheat in water limited environments **(Debora MacKenzie, 1994).**

Herbicide : **Glyphosate:** As of 1999, the most common GM trait was the Glyphosate tolerance The Glyphostae interferes with the Shikimate pathway in plants and kills them eventually. This is an important pathway for the synthesis of Aromatic Amino Acids, tyrosine and tryptophan. The animals acquire the required aromatic amino acids from their diet as the Shikimate pathway is absent in them. It mainly inhibits the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS). This trait was developed because of the highly toxic nature of the prevalent herbicides, which were in use for the grain and grass crops and were ineffective against the narrow-leaved weeds. Thus, it was highly desirable to develop the crops that could withstand spraying with Glyphosate to reduce the environmental pressure and providing edge to the farmers **(Debora MacKenzie, 1994)**.

Bromoxynil, Glufosinate and 2,4-D: Bromoxynil resistant tobacco plants are developed **(**Gianessi,**)**. Glufosinate resistant crops are also commercialized **(Gianessi *et al.*, 2016)**. The research for multiple herbicide tolerant crops is also underway to help farmers use multiple herbicides thus reducing herbicide pressure **(Mark Ganchiff, 2013)**. Dow's Enlist Duo maize was registered in October 2014, which provided resistance to both Glyphostae and 2, 4-D in nearly six states **(Anonymous, 2014)**.

Pest Resistance: **Insects:** Rice, corn, tobacco and some other crops have been engineered for the expression of genes encoding for insecticidal proteins from the *Bacillus thuringiensis* (Bt) **(Vaeck, 1987)**. The total volume of insecticidal active ingredients used in the US reduced drastically by over 100 thousand tons. This reduction was triggered by growing of the Bt crops during the period of 1996-2005.

Viruses: The Cucumber Mosaic Virus, despite its name infects a wide variety of plants such as papaya, potato and squash. GM crops are developed to resist this severe disease **(Anonymous, 2001)**. GM Potatoes were also produced for imparting resistance against Potato leaf roll virus and Potato Virus Y in 1998, but was soon withdrawn due to poor sales **(Anonymous, 2016)**.

1. **By Products:** In 2012, the FDA approved the first plant-produced pharmaceutical, for the treatment of Gaucher's disease. Therapeutic antibodies are produced by modifying the genome of tobacco plants **(Jha, 2012)** another by product is the Biofuel that can be prepared by Algae **(Carrington, 2012**). There is an extensive research going on in Singapore for the production of GM Jatropha for Biofuel production **(*http//www.isaaa.org.)*.** The chemically liable lignin bonds are also very useful for the cereal crops **(Anonymous, 2016)**. The production of Bioplastics and industrially useful starch by potato is being taken seriously by the scientists all over the world **(Anonymous, 2010)**.

Bioremediation: Genetically modified plants are used for the bioremediation and amelioration of the contaminated soils. Mercury, Selenium and other Organic pollutants are controlled by GM Crops **(Meagher, 2000)**. Oil spills are difficult to control, so various Hydrocarbonoclastic bacteria (HCCB) can be used **(Martins, 2008).**

Asexual Reproduction: Crops such as maize reproduces sexually, thus the desirable gene is not stable in the next generation. The farmers are always dependent on the purchased seeds and are always in a state of loss. GM Crops are developed for the self pollination so that the harvested seeds are used for the sowing purpose **(Daniel Charles, 2003)**.

GM crops in India

Bt Cotton: The US seed company Monsanto jointly with the Maharashtra Hybrid Seeds Company (Mahyco) developed the Bt Cotton to counter the problem of bollworms that had caused severe damage to the cotton crop in the past by the incorporation of *Bacillus thuringiensis* gene into the cotton plant. It was the first and only transgenic crop that was approved by the GEAC for commercial cultivation in nearly six states namely, Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra and Tamil Nadu. It was later on extended to Punjab and Haryana. The government data suggests that the area under Bt cotton was increased from 0.7 lakh acres in Kharif-2002 to 2.3 lakh acres in Kharif-2003 and further increased to 12 lakh acres in 2004 Kharif **(Latha Jishnu, 2009)**. As per the government reports India was 4th largest adopter of biotech crops with 7.6 million hectares **(Lola Nayar, 2009)**. On the one hand, it is claimed that the Bt Cotton has revolutionized Indian cotton farming as 90% of the cotton grown area is covered by it, increasing the yield by 50% in certain regions. But certain claims are made by the civil societies that go against it. It is said that the farmers face adverse economic conditions because of Bt cotton. Some more problems are high priced seeds, changed pest ecology in cotton fields, increment in the incidence of pests and diseases, thus necessitating excess use of pesticide in the cotton field. It is also believed that Bt cotton is not able to sustain adverse weather conditions.

Bt Brinjal: In India, Brinjal is one of the most popular vegetable. It is mostly grown as a cash crop by small farmers. The main growing states are Andhra Pradesh, Bihar, Karnataka, Maharashtra, Odisha, Tamil Nadu, Uttar Pradesh and West Bengal. It is estimated that about 50% to 70% loss is caused by the Fruit and Shoot Borer. Bt Brinjal was produced by inserting a gene Cry 1Ac from the soil bacterium *Bacillus thuringiensis*. It is reported that upon the ingestion of toxin by the insect, there would be a disruption in the digestion process. The GEAC has cleared the Bt Brinjal, making it the first GM food in India to get the approval of the apex body but the final call has to be taken by the government on this matter.

GM Mustard: The Dhara Mustard Hybrid-11 that is known as DMH-11 is a genetically modified hybrid variety of the *Brassica juncea*. The variety was developed by Professor Deepak Pental to reduce India's dependency on imported edible oil. It was created by the use of transgenic technology that involved Bar, Barnase and Barstar gene system. Male sterility is provided by the Barnase gene, while the Barstar gene helps in restoration of the fertile seed production ability. Bar gene enables it to produce phosphinothricin-N-acetyl-transferase, which is responsible for Glufosinate resistance. It has come under major public scrutiny, as it is supposed to give rise to a super weed. The DMH-11 is tolerant to the Glufosinate, which is thought to give rise to liberal spraying of the herbicide. Though such claims lack any scientific base and are still not proved.

Other GM Crops (*http://www.igmoris.nic.in*):

Cabbage and Cauliflower- Insect resistance.

Potato- Transgenic dwarf potato, Disease resistance, Reduction in cold induced sweetening and chip color improvement.

Cotton ,Rice and Sorghum- Insect resistance.

RRF Cotton and Corn- Insect resistance and Herbicide tolerance.

Groundnut- Virus resistance.

Pros of the GM Food

1. Food Security.
2. Nutritional security.
3. Development of crops that are resistant to abiotic stresses (flood, draught, frost and salt).
4. Development of biotic stress tolerant crops such as insects and pests.
5. Improved crop and nutritional quality.
6. Less pressure on non-renewable sources.
7. Development of nutrient efficient crops.
8. Reduction in the use of pesticide and insecticide.
9. Better environmental conditions.
10. Remunerative for the farmers.

Cons of the GM Foods (Anonymous, 2010)

1. **Environmental concerns:** The GM foods are not yet proven to be completely safe for environment. There is a need of substantial research regarding this.
2. **Allergic Reactions:** There was a research conducted by the Brown University, that the GM foods can pose significant allergy risks to the people. In some cases, the proteins that a person is allergic to may be added to the food item which is not allergic for him.
3. **Minimal Biodiversity:** There is a strong risk of the loss of Biodiversity. As, when we remove a pest, we also remove a potential source of food for another organism; thus disturbing the whole food chain.
4. **Different and Unusual taste:** the GM foods are found to have a different taste as compared to their original counterparts.
5. **Decreased Antibiotic Efficacy:** Some GM crops have the genes of resistance from a virus or disease. When a person consumes them, then a decreased antibiotic efficacy is shown by him.
6. **Exploitation by converting them into weapon:** If the GM crops are used properly, then they can cause severe havocs and can be used to kill large number of people in a state of war.
7. **New and Unknown Diseases:** They are thought to create new diseases in human beings. There is a great debate going on about the GM regarding human health.
8. **Widening gap of the Corporate Sizes:** the large capital required for the GM foods can result in the consolidation of wealth in the hands of few rich industrialists, thus creating a social gap.
9. **Safety Concerns:** It is contested that the GM foods can cause death and thus they should be analyzed before consumption.
10. **Gene Spilling:** There could be dramatic effects of the release of pollens from the genetically altered plant into the wild varieties. Though, there is still a need of research in this field.
11. **Cross-Pollination:** There is a difficulty in distinguishing the difference between GM and non GM, because in cross pollination the pollens travel a long distance and can easily contaminate an organic field.
12. **Uncertain Food supply:** The GM foods have patented seeds. So, it is mandatory to purchase them through signing certain agreements; thus creating risk for the regular food supply.
13. **Transfer of genes:** A constant risk is there of the GM genes mixing with the wild ones, thus creating undesirable changes.
14. **Conflicts between the authorities:** Higher tariffs are implemented by the authorities over the GM food in many cases.
15. **Economic Concerns:** It is a costly and lengthy process to bring the GM foods in the normal market chain. The developer of the technology also wants a suitable royalty for the GM product, so ultimately it is not economically viable for the small farmers to purchase these seeds.

The Way Forward:

The major issue with the GM foods is the prevalent public perception regarding their nature and after effects. It is the collective responsibility of the governments and scientific community all over the world to clear the air around them. The governments should ensure a conducive environment is there for the research and development of GM foods and there is technology transfer between the governments. The claims that are made against the GM foods are also proving to be obstacles in the path of adoption of this technology.

The claims that are made have neither a scientific basis nor they are disproved. So, a state of ambiguity is present regarding The GM foods. There should be a positivity regarding every technology. It should be improved if found to have certain issues. It is important in terms of feeding the ever rising world population and ensuring food and nutritional security.

Conclusion

Genetic engineering and its application in agriculture can prove to be instrumental in providing food and nutritional security in the case of developing countries especially India. A majority of population is dependent on agriculture as a mainstay for livelihood in these countries. Science cannot be declared as risk free. If a scientific innovation is able to counter a certain issue, so it may pose some new problems in front of us. It is the duty of society to decide whether we are ready for the GM foods. The arguments in favor and against of the GM foods will go on until the scientific community clears the air around it. With the determination which are scientists have, it is a surety that it will happen sooner than later. But, till than the irrational criticism should not happen against the GM crops and even if they have any issues, they must be addressed through proper channel. Only providing information regarding the presence of GM will also not serve any purpose, until we have the information regarding their implications. To sum up in the words of **(Swaminathan, 2008)**, “GM foods have the potential to solve many of the world’s hunger and malnutrition problems, and to help protect and preserve the environment by increasing yield and reducing reliance upon chemical pesticides. Yet there are many challenges ahead for governments, especially in the areas of safety testing, regulation, industrial policy and food labeling.”

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