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Environmental Concerns for Transgenic Plants: An Overview

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ABSTRACT

The emerging issues of food security and nutritional security have led to the development of newer technologies in agriculture sector over the years. The conventional plant breeding approach leading to the release of several potential high yielding varieties of different crops contributing to global food security is not keeping pace with global population expansion over the years. The intervention of technological developments in agriculture has led to landmarks in the form of 'green revolution', 'gene revolution' and 'evergreen revolution'. The major limitation of conventional plant breeding is the availability of narrow gene pool which has led to the emergence of transgenic technology having immense potential to avail wider gene pool without any sexual barrier.The transgenic technology is now well established technology leading to the release of several commercialized transgenic plants globally, though several issues have been raised time to time. The acceptability of the transgenic technology has alwaysbeen questioned owing to biosafety concerns,risks associated with non-target species, possible threat to biodiversity, possibility of gene flow, perturbation in soil biota and tendency of developing resistance among pests for disease resistant transgenic plants.The so called environmental concerns of transgenic plants need to be scientifically addressed case by case so as to explore the tremendous potential of transgenic technology for crop improvement.The present status of transgenic plants, potential applications, environmental concerns, gene containment strategy has been discussed in this review paper.

INTRODUCTION

The emerging issues of food security and nutritional security have led to the development of newer technologies in agriculture sector over the years. The conventional plant breeding approach leading to the release of several potential high yielding varieties of different crops contributing to global food security is not keeping pace with global population expansion over the years. The intervention of technological developments in agriculture has led to landmarks in the form of 'green revolution', 'gene revolution' and 'evergreen revolution'. The major limitation of conventional plant breeding is the availability of narrow gene pool which has led to the emergence of transgenic technology having immense potential to avail wider gene pool without any sexual barrier.The transgenic technology is now well established technology leading to the release of several commercialized transgenic plants globally, though several issues have been raised time to time. The acceptability of the transgenic technology has alwaysbeen questioned owing to biosafety concerns,risks associated with non-target species, possible threat to biodiversity, possibility of gene flow, perturbation in soil biota and tendency of developing resistance among pests for disease resistant transgenic plants.The so called environmental concerns of transgenic plants need to be scientifically addressed case by case so as to explore the tremendous potential of transgenic technology for crop improvement.The present status of transgenic plants, potential applications, environmental concerns, gene containment strategy has been discussed in this review paper.

Transgenic Plants: Present Status

Genetically Modified Organisms (GMO), are generally referred as organisms in which the genetic material i.e. DNA has been altered or modified using tools of genetic engineering to get the desired features. This technology is often called 'recombinant DNA technology' or 'genetic engineering' and the resulting organism is said to be 'genetically modified', 'genetically engineered' or 'transgenic'.The transgenic plants are now more popularly referred as 'Biotech crop'. The discovery of the molecular structure of deoxyribonucleic acid (DNA) by Watson and Crick in theearly 1950s (Watson and Crick, 1953) paved the way for modern biotechnology which focuses ongene manipulation to enhance the ability of specific organisms to perform tasks or produce substancesfor human benefit. Today this modern biotechnology finds diverse applications in agriculture, horticulture, forestry, environmentalremediation, medicine, and forensic science (Mannion, 2007; Murphy, 2007).The first field trials of genetically engineered plants occurred in France and the USA in 1986, when tobacco plants engineered for herbicide resistance were released (James,1996).In 1987, Plant Genetic Systems led by Marc Van Montagu and Jeff Schell at Ghent, Belgium was the first company to develop genetically engineered tobacco plants with potential for insect tolerance by expressing genes encoding for insecticidal proteins from Bacillus thuringiensis(Bt) (Vaecket al.,1987). The People's Republic of China was the first country to allow commercialized transgenic plants, introducing a virus-resistant tobacco in 1992(James, 1997).The first genetically modified crop approved for sale in the U.S., in 1994, was the FlavrSavr tomato with a longer shelf life (Bruening and Lyons,2000). In 1995, Btpotato was approved as safe by the Environmental Protection Agency, making it the first pesticide producing crop to be approved in the USA (James, 1997). As per the report of ISAAA, in 2013, 11 different transgenic crops were grown commercially on 365 million acres (148 million hectares) in 28 countries such as the USA, Brazil, Argentina, India, Canada, China, Paraguay, Pakistan, South Africa and Uraguay. The global area of biotech crops is listed in Table-1.

The important GM traits are herbicide tolerance (Tappeser et al., 2014), insect resistance (Tabashnik et al., 2013), disease resistance (Wally and Punja, 2010), virus resistance (Tabassum et al., 2013),stress tolerance (Cabello, 2014), improvement of crop yield and quality (Ortiz, 1998),delayed ripening (Xie et al., 2013), molecular farming (Schillberg, 2013), and also for enhanced biodegradation and phytoremediation of organic xenobiotics (Abhilash et al., 2009).A record 175.2 million hectares of biotech crops were grown globally in 2013, at an annual growth rate of 3%, up 5 million from 170 million hectares in 2012. This year, 2013, was the 18th year of commercialization, 1996-2013, when growth continued after a remarkable 17 consecutive years of increases; notably 12 of the 17 years were double-digit growth rates.Currently, there are a number of food species for which a genetically modified version is being commercially grown. Some of the important biotech crops with desired features (www.nass.usda.gov)are shown in Table 2.

Major concerns

The advent of transgenic technology has also led to several issues and controversies related to food safety which was not scientifically driven but more because of ignorance of the reality. The biosafety implications of the field release of transgenic plants have attracted global attention. The potential environmental impacts of any transgenic crop will vary depending on the crop's characteristics, the ecological system where it is being grown, its management and the regulatory mechanism. The issues pertaining to biosafety of transgenic crops has been addressed by molecular biologists, ecologists and environmentalists to reveal the perceived ecological risks. Substantial efforts has been made to do extensive research for analyzing the short and long term effects of transgenic crops on the environment prior to the commercialization so that it can be safely released in the developing countries which are rich sources of genetic biodiversity.

Table 1 Global area of Biotech crops in 2013 by different countries (based on James, 2013).

Rank	Country	Area (10^6ha)	Biotech Crops
1	USA*	70.1	Soybean, maize, cotton, canola, squash, papaya, alfalfa, sugarbeet
2	Brazil*	40.3	Soybean, maize, cotton
3	Argentina*	24.4	Soybean, maize, cotton
4	India*	11.0	Cotton
5	Canada*	10.8	Canola, maize, soybean, sugar beet
6	China*	4.2	Cotton, tomato, poplar, petunia,papaya, sweet pepper
7	Paraguay*	3.6	Soybean, maize, cotton
8	South Africa*	2.9	Cotton, maize, soybean
9	Pakistan*	2.8	Cotton
10	Uruguay*	1.5	Soybean, maize
11	Bolivia*	1.0	Soybean
12	Philippines*	0.8	Maize
13	Australia*	0.6	Cotton, canola
14	Burkino Faso*	0.5	Cotton
15	Myanmar*	0.3	Cotton
16	Spain*	0.1	Maize
17	Mexico*	0.1	Cotton, soybean
18	Colombia*	0.1	Cotton
19	Sudan*	0.1	Cotton
20	Chile	<0.1	Maize, soybean, canola
21	Honduras	<0.1	Maize
22	Portugal	<0.1	Maize
23	Cuba	<0.1	Maize
24	Czech Republic	<0.1	Maize
25	Costa Rica	<0.1	Cotton, soybean
26	Romania	<0.1	Maize
27	Slovakia	<0.1	Maize
Total		**175.2**	

*regarded as the major producers

Some of the serious ecological risks envisaged with the commercializationof transgenics are:
(I) Possibility of transfer of transgenes (especially from herbicide-resistant crops) to wild or weedy relatives.
(ii) Increasing trend of monoculture leading to loss of crop genetic diversity with possible genetic erosion over a period of time.
(iii) Possibility of common insect pests developing resistance to crops with Bt (*Bacillus thuringiensis*) toxin.
(iv) Possibilities of undesired genetic recombination leading to development of new virulent strains of virus, especially in transgenic plants engineered for viral resistance with viral genes.
(v) Possibilities of vector-mediated horizontal gene transfer and recombination creating new pathogenic bacteria.
(vi) The possibility of reduction or enhancement of fitness of nontarget organisms owing to the incorporation of transgenic traits.
(vii) Perturbation in soil biota owing to the accumulation of the Bt toxins.
(viii) The natural control of insect pests will be disturbed owing to predominance of Bt toxins.
(ix) Reduction of productivity due to yield drag effect on transgenic crops is also perceived.
(x) Possibility of contamination of natural flora and fauna owing to different trasngenes by advocating transgenic technology.
(xi) Vulnerability of crops to environmental changes may be increased and there is possibility of developing new pests and diseases.
(xii) The agroecosystem biodiversity may be threatened owing to cultivation of transgenic crops.

I*mpact on non-target organisms*

The influence of biotic stress in reduction of overall crop productivity worldwide has led to development of strategies for insect resistant crops both using classical breeding and modern transgenic technology. There have been limited successes in developing insect resistant crops by breeding owing to the availability of limited gene pool. The transgenic technology has great potential for developing insect resistance transgenic crops and various potential genes have been characterized over the years. The best approach for developing transgenic crops resistant to different insect pests is through the expression of the cry (crystal delta-endotoxins) and cyt (cytolysins) genes from Bacillus thuringiensis (Bt). There are concerns that these toxins could target predatory and other beneficial or harmless insects as well as the targeted pest insect. The proteins produced by Bt have been used as organic sprays for insect control in France since 1938 and the USA since 1958 with no ill effects on the environment reported. While cyt proteins are toxic towards the insect orders Coleoptera (beetles) and Diptera (flies), cry proteins selectively target Lepidopterans (moths and butterflies). In general the toxic mechanism involves binding of the cry proteins to specific receptors on the membranes of mid-gut (epithelial) cells of insects, resulting in rupturing of those cells. Any organism that lacks the appropriate receptors in its gut cannot be affected by the cry protein. This is considered by regulatory agencies to evaluate the effect of Bt crops to non-target organisms before commercialization (Romeis et al, 2010).A controversy regarding Bt was highlighted in 1999 in a paper published in Nature Journal revealing that in lab environment, pollen from Bt maize dusted onto milkweed could harm the monarch butterfly (Losey et al., 1999).This was followed by a collaborative research exercise carried out over the next two years by several groups of scientists in the US and Canada, looking at the effects of Bt pollen in both the field and the laboratory. This extensive risk assessment experiments concluded that any risk posed by the corn to butterfly populations under real-world conditions was negligible (Sears et al., 2001). This was later on supported by report that "the commercial large-scale cultivation of current Bt–maize hybrids did not pose a significant risk to the monarch population" and noted that despite large-scale planting of GM crops, the butterfly's population is increasing (Gatehouse et al., 2002). An analysis of laboratory settings found that Bt toxins can affect non-target organisms, usually organisms closely related to the intended targets (Lövei et al., 2009). There is a possibility of transfer of transgene for Bt toxin to wild or weed relatives of GM crop species by hybridization. These wild species may benefit by escaping damage by insect herbivory and may become serious weeds or may also outcompete and locally extinguish other species in natural environment.These issues need to be addressed prior to the release of transgenic crops for commercialization globally.The field grown transgenic plants may interact directly with organisms that feed on the crops, and indirectly with other organisms in the wider food chain. The pollen from the transgenic plants behaves like the pollen of any other crop and this might lead to transfer of the pollen from transgenic crop to normal crops growing in nearby areas. This has been a major concern for environmentalists perceiving the unknown effects of genetically-engineered crops on non-target species, and about the possible gene flow to other plants, animals and bacteria. In fact advocates of GM or biotech crops supports the transgenic technology highlighting the potential of biotech crops as environmental friendly through a reduction in the use of pesticides (Conner et al., 2003) and also reduction in greenhouse gas emissions (Brookes et al., 2012).Some of the important concerns of environmentalists in light of development of transgenic plants over the years are discussed below.

Biodiversity may be threatened

There is concern that transgenic crops might lead to decrease in genetic diversity as GM varieties will mask the use of other cultivars ultimately leading to extinction.

Table 2: List of some of the Biotech crops with desired features

Crops	Introduced traits
Grapes	Insect resistance via producing Bt proteins
Poplar trees	Herbicide toleranceto simplify weed control
Eucalyptus	Modified lignin composition for Pulp and paper processing
Alfalfa	Resistance to glyphosate or glufosinate herbicides
Carnation	Modified colour and herbicide tolerance
Canola	Resistance to herbicides (glyphosate or glufosinate), High laurate and oleic acid content (to make less saturated fats)
Chicory	Resistance to herbicides (glyphosate or glufosinate)
Maize	Resistance to glyphosate herbicides. Insect resistance via producing Bt proteins Increase Lysine content Transgenic producing Lactoferrin Transgenic producing Gastric lipase
Cotton	Insect resistance Herbicide tolerance
Papaya	Resistance to the papaya ringspot virus.
Potato	Insect and virus resistance (NewLeaf: Bt resistance against Colorado beetle and resistance against 2 viruses) Amflora: resistance against an antibiotic (for selection) and modification for better starch production Production of vaccine against *E. coli* labile enterotoxin, hepatitis B, Norwalk virus
Rice	expression of beta-carotene for high vitamin A content (Golden Rice) increase tryptophan content decreasetheglutenin and albumin content transgenic forlactoferrin production
Soybeans	Resistance to glyphosate or glufosinate herbicides; Insect resistance High oleic acid content, low linolenic acid content (to make less saturated fats)
Squash	Multiple virus resistance (resistance to watermelon, cucumber and courgette yellow mosaic viruses)
Sugar beet	Resistance to glyphosate, glufosinate herbicides
Sugarcane	Resistance to certain pesticides High sucrose content.
Sweet peppers	Resistance to cucumber mosaic virus
Tomatoes	Suppression of the enzyme polygalacturonase (PG)for retarding fruit softening
Wheat	Resistance to glyphosate herbicide
Lettuce	Increase Ferritin content
Tobacco	Transgenic for production of vaccine against Norwalk virus Production of dental carries antibodies Production of non-Hodgkings lymphoma antibodies
Spinach	Vaccine against rabies
Arabidopsis	Human intrinsic factor production
Flax	Herbicide-resistance
Sweet corn	Genetically modified to produces its own insecticide
Rape seed	Resistance to certain pesticides and improved rapeseed cultivars to be free of erucic acid and glucosinolates

Further there are also possibilities that the widespread use of GM crops developed to resist agrochemicals will lead to increased use of those agrochemicals, which in turn might cause damage to the environment and to biodiversity. There has been a comparative study regarding the influence of GM cotton crops on genetic diversity in USA and India (Carpenter, 2011). Further an attempt was made to investigate the effects of Bt crops on soil ecosystems revealed that in general it does not have consistent, significant, and long-term effects on the microbiota and their activities in soil(IcozandStotzky, 2008). The diversity and number of weed populations has been shown to decrease in farm-scale trials in the UK and Denmark ascomparedtoherbicide resistant crops with their conventional counterparts (Bohanet al., 2005;Strandberget al., 2005).Recently a correlation between the reduction of milkweed in farms that grew glyphosate-resistant crops and the decline in adult monarch butterfly populations in Mexico was reported(Pleasantsand Oberhauser, 2012).

Possibility of outcrossing by transgenic crops to non-target crops

There is a possibility of transfer of genes from transgenic crops to another organism just like an endogenous gene by means of process known as outcrossing. This can occur in any new open-pollinated crop variety, with newly introduced traits potentially crossing into nearby crop plants of the same or sometimes closely related species. There are possibilities for producing species of weeds resistant to herbicides more popularly known as 'superweeds'(Arencibia, 2000) and could contaminate nearby non-genetically modified crops or organic crops, or could disrupt the ecosystem (Eugene, 2013). This concern is more pertinent if the transgenic crops has a significant survival capacity and can increase in frequency and persists in natural populations.

Threat of emergence of resistant insect pests owing to development of several transgenic insect resistant crops

It is a well-known that resistance evolves naturally once the population has been subjected to intense selection pressure in the form of repeated use of a single herbicide or insecticide. Bollworm resistance to first generation Bt cotton has also been identified in India, Australia, China, Spain and the United States (Bagla, 2010). The strategy to delay the emergence of Bt resistant pests has been to have non-GM refuges within the GM crops to dilute any resistant genes that may arise or more recently to develop GM crops that have multiple Bt genes that target different receptors within the insect (Christou et al., 2006).

Threat to soil biota

The potential impact of transgenic plants on soil biota largely depends on the persistence of transgene-derived proteins (especially Bt endotoxin) and its activity in the soil. There is a possibility that the transgenic plants might damage the beneficial microbes of soil such as rhizobia, mycorrhizae, earthworms, nematodes, etc. associated with decomposition and nutrient cycling. Several crops have been engineered for insect resistance through Bt toxin. The root of such plants exudates these toxins into the soil, where the activity is retained for a long time and might stimulate a key change in soil biota. The soil fertility might be reduced owing to adverse effects on microbial communities by incorporation of transgenes in soil (Velkov et al., 2005).Studies on the influence of soil processes by the transgenes by monitoring the plant litter decomposition, which is considered to be a key indicator of soil ecosystem has revealed both positive and negative results .The decomposition rates on non-transgenic and transgenic plants must be compared for each transgenic plant(especially Bt-transgenes) so as to make any specific conclusion.

Effect on sustainable agriculture and organic farming

Since time immemorial, alternative agriculture techniques have emerged for making it more sustainable. There have been used many indigenous approaches to protect the farm produce from insects and weedsand also, viz. rotations, strip cropping, green manure and biological controls.Among them, organic or biological farming is most admired. Organic farmers claim that pests in general are not a severe problem in organic systems. Healthy plants with balanced nutrition are igenerally better able to resist pest attacks. These natural approaches of crop protection are an essence of farming but with the inculcation of transgenic crops these methods are becoming extinct as farmers are more inclined to protection of their crops by monoculture system. Further, transgenic crops are potent threat to organic farming because of the contamination caused to organic farms by cross pollination via insects and winds. Cross pollination can circulate transgenes to different farms resulting unintentional propagation transgenic crops in organic farms.

Gene Containment

The development of weeds resistant to glyphosate, the most commonly applied herbicide, could mean that farmers must return to more labour intensive methods to control weeds, use more dangerous herbicides (so increasing the risk of erosion). A 2010 report by the National Academy of Sciences stated that the advent of glyphosate-herbicide resistant weeds could cause the genetically engineered crops to lose their effectiveness unless farmers also use other established weed management strategies. The development of Genetic use restriction technology more popularly known as 'Terminator gene technology' was meant to curtail environmental threats of GM crops by allowing the production of crops with sterile seeds, which would prevent the escape of genetically modified traits (Serageldin, 1999). These technologies themselves caused several controversies, as there are fears the technology itself, and the patents on them, would allow companies to further control the market for seeds.Prior to the release of transgenic crops to the market, extensive scientific evaluation is done for the biosafety so as to confirm that it is "substantially equivalent" to its natural counterpart (Park et al., 2011). Other than 'Terminator gene technology' several other strategies have been developed for preventing the transfer of foreign genes from GM crops to other plants (Daniell, 2002; Hill et al., 2007) .

Table 3 Techniques for gene containment.

Technique	Advantages	Disadvantages
Maternal inheritance	High-level transgene expression, multi -gene engineering in a single transformation event, lack of gene silencing, position effect and pleiotropic effects	Processing of expressed proteins
Male sterility	Prevents out-crossing from GM crop to weeds or related non-GM crops.	Seeds produced fromnuclear male sterile GM crops by cross -pollination from seeds,may be a serious concern because seedsof such hybrids will produce fertile pollen that would carry the GM trait.
Cleistogamy	Only self pollination takes place that prevents outcrossing	Genes to modify floral design not readily available.
Apomixis	Because seeds are produced without fertilization it controls both outcrossing and hybrid traits can be fixed.	Unusual trait, found only in few plants
Incompatible genomes	It prevents recombination after pollination	Not applicable to crops having homologous recombination
Temporal and tissue - specific control via inducible promoters	Gene activated only when product is necessary or excised before flowering.	Not applicable for genes required throughout the plant's life.
Transgenic mitigation	Introduced genes is advantageous or neutral for transgenic crop but harmful for weeds	May cause extinction of weedy relatives, and therefore reduces biodiversity

Need For Stringent Regulation for The Release of Transgenic Crops Globally

The transgenic technology has witnessed several controversies over the year which ultimately led to problems regarding the acceptance of transgenic crops in many countries. In most countries there is a need for substantial environmental studies prior to the approval of a transgenic /GM plant for commercialization.

There are various pros and cons for complete prohibition of GMOs as well as labeling of genetically modified food or other products (Scatasta et al., 2007).The European Union, Australia, New Zealand, China, India and other countries require GMO labeling, while others make GMO labeling voluntary (Gruère and Rao, 2007). GMO labeling is not required in the United States, although there have been numerous efforts to pass labeling laws. In 2012, the U.S. state of California voted against Proposition 37, which would have required the labeling of genetically modified food (Vaughan,2012).

GM crops play a key role in contemporary large scale agriculture, which involves monoculture, use of herbicides and pesticides, use of equipment that requires large amounts of fossil fuels, and irrigation. Proponents of modern agriculture, including GM crops, tout the low prices and wide array of choices the system has produced, and claim that technology must be applied to agriculture if we are to feed a growing world population (Erickson and Mintert, 2009). Several regulatory bodies have been constituted in respective countries for the safe release of GM crops though still there is paucity of stringent regulation worldwide for the commercialization of transgenic crops and proper monitoring of GM crops for possible threat to environment and existing genetic diversity.

In US, Four federal district courtsuits have been brought against Animal and Plant Health Inspection Service (APHIS), the agency within USDA that regulates genetically modified plants. Two involved field trials (herbicide-tolerant turfgrass in Oregon; pharmaceutical-producing corn and sugar in Hawaii) and alfalfa and GM (Hughen and Smith, 2008).

Initially APHIS lost all four cases, with the judges ruling they failed to diligently follow the guidelines set out in the National Environmental Policy Act. However, the Supreme Court overturned the nationwide ban on GM alfalfa (Monsanto and Geertson, 2010) and an appeal court allowed the partial deregulation of GM sugar beet crops.

In Africa, in 2002, Zambia refused emergency food aid from developed countries, fearing that the food is unsafe. During a conference in the Ethiopian capital of Addis Ababa, Kingsley Amoako, Executive Secretary of the United Nations Economic Commission for Africa (UNECA), encouraged African nations to accept genetically modified food and expressed dissatisfaction in the public's negative opinion of biotechnology. Studies for Uganda show that transgenic bananas have a high potential to reduce rural poverty but that urban consumers with a relatively higher income may reject the introduction (Kikulwe et al., 2011). In India, there were many controversies over GM crops and GM food. In Maharashtra, Karnataka, and Tamil Nadu, the GM cotton yields had an average 42% increase in yield with GM cotton in 2002, the first year of commercial GM cotton planting. However, there was a severe drought in Andhra Pradesh that year and the parental cotton plant used in the genetic engineered variant was not well suited to extreme drought, so Andhra Pradesh saw no increase in yield. Drought resistant variants were developed with substantially reduced loss (James, 2011).There have been several reports about the economic and environmental benefits of GM cotton in India (Bennett et al., 2004; Subramanian and Qaim, 2012).Recently it has been reported that Bt cotton increased yields, profits, and living standards of smallholder farmers in India (KathageandQaim, 2012). However, recently there was report about cotton bollworm developing resistance to Bt cotton and the Indian Agriculture Ministry linked farmers' suicides in India to the declining performance of Bt cotton for the first time. Consequently, in 2012 the state of Maharashtra banned Bt cotton and ordered a socio-economic study of its use by independent institutes. Indian regulators cleared the Btbrinjal, a genetically modified eggplant, for commercialization in October 2009 but due to opposition from some scientists, farmers and environmental groups it could not be released. On 1 January 2013, a new law came into effect that required all packaged foods containing any genetically modified organisms to be labeled as such. The law faced criticism from consumer rights activists as well as from the packaged food industry as there was no logistical framework or regulations established to guide implementation and enforcement of the law.

CONCLUSION

The technological innovation in agriculture is a prerequisite for attaining global food and nutritional security but not at the cost of environmental degradation. The advent of transgenic technology has greatly influenced the agricultural sector as evident from the commercialization of several transgenic crops worldwide and substantial increase in the area of cultivation of GM crops over the years. The technology has a lot of potential for crop improvement but needs to be extensively evaluated for various concerns related with biosafety, invasiveness, effects on nontarget species, potential of horizontal transfer of transgenes into environment, possible adverse effects on the soil biota, adverse implications for biodiversity and sustainable agriculture and so on. The acceptability of transgenic technology solely depends on these concerns and it has to be scientifically carried out case by case for both short term and long term effects before commercialization.The government intervention in the form of stringent biosafety testing, regulation, national and international policies, labelling of GM foods will be highly appreciated by involving experts from all sectors so that it is not biased. The environmental concerns are important though it requires long term monitoring of transgenes and should be compared with the other environmental damages being made by various anthropogenic sources owing to industrialization, urbanization etc. Many people feel that genetic engineering is the inevitable wave of the future and that we cannot afford to ignore a technology that has such enormous potential benefits. In general, we conclude that large-scale use of transgenic plants do not display considerable negative effects on the environments and, further some transgenic plants can improve the corresponding environments and human health because their production considerably reduces the load of chemical insecticides and herbicides. However, we must proceed with caution to avoid causing unintended harm to human health and the environment as a result of our enthusiasm for this powerful technology.

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