BAIG ET AL (2017), *FUUAST J.BIOL*., 7(2): 193-198

GM CROPS AND THEIR ENVIRONMENTAL RISKS: A MINI OVERVIEW

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خلاصہ

دنیا کے چند ملکوں میں غزائی کی کی وجہ سے بنیادی طور پر تبدیل شدہ فصلیں استعمال ہو رہی ہیں یہ دنیا کے اکثر ملکوں میں اسلئے استعمال نہیں کی جا رہی کہ کوئی نہیں جانتا کہ انکا استعمال کرنے سے کیا خراب اثرات پڑ سکتے ہیں۔ یہ فصلیں جنیاتی انجیئرینگ کے طریقہ کار کو استعمال کر کے پیدا کی جاتی ہیں مختلف تجربہ ان جیسی فصلوں پر کیا گیا۔ جنگلی پیداوار میں مختلف اقدام اٹھائے گئے۔ ان فصلوں کے فائدوں کے علاوہ ماحولیاتی اعتبار سے خراب اثرات پڑ سکتے ہیں انکے بارے میں تحقیق جاری ہے۔

Abstract

Genetically modified crops have been included in the diet of people of some countries of the world due to food shortage problems. They are not being consumed in most of the countries of the world as people consider using them can prove to be harmful for them. Genetically modified crops are being produced widely by applying plant genetic engineering approaches and these are helping us in a variety of ways. No one is certain about the harmful aspects of the GM crops. Safety analysis being carried out in order to market genetically modified crops for public usage. Production of a genetically modified crop involves different steps. Along with many benefits of the GM crops, there are some environmental risks which are attributed to the GM crops. Further research is on the way to study the efficiency and harms related to GM crops.

Introduction

For thousands of years farmers have been modifying crop plants to improve their characteristics as yield, taste, nutritional quality and resistance to pathogens or diseases. Plants comprising desired characteristics are selected and further subjected to breeding. But this widely used classical method is limited by the natural barriers. Today use of genetic modification has enabled scientists to work on gene level and transfer the genes from one organism to another to change its characteristics for human future benefits (Glass and Fanzo 2017). Production and use of Genetically Modified Crops giving better yield, insect resistant, herbicide tolerant and resistant to other plant diseases are now considered to be the key for 1 billion people suffering from prevailing hunger, poverty and malnutrition in developing countries (Lu *et al*. 2017).

Today, the advances in biotechnology and genetic engineering has enabled to develop a number of genetically modified (GM) crops or transgenic crops and now referred to as biotech crops carrying novel traits for commercial use and agriculture production. These include pest resistant cotton, maize, canola (mainly *Bacillus thuringiensis* or bt), cotton and viral disease resistant (VR) potatoes, herbicide glyphosate resistant (HT) soybean, papaya and rice. Moreover, many transgenic crops are under development and not yet commercially released with traits for biofortification, phytoremediation and production of pharmaceuticals, such as rice with high level of carotenoid for production of Vitamin A (e.g. golden rice) and bananas with vaccines (Kathage, et al. 2017).

The most compelling benefits for production biotech crops are their capability in contribute to (Adenle، 2011):

- increasing crop yield and thus contribute to more affordable food productivity and fiber security (Lu, *et al*., 2017)
- self-sufficiency which means optimizing productivity‘ and production on a nations own sufficient arable land
- conserving biodiversity GM crop development serves as a “land-saving technology” capable of higher productivity thus can help preclude deforestation and conserve forest biodiversity
- mitigating some of the challenges associated with climate change nature challenges such as increasing frequency and severity of droughts, floods, epidemics, changes in temperature, rising sea levels exacerbating salinity and changes in temperature can be successfully faced by GM crops which are also capable of reducing greenhouse gases

- The improvement of economic, health and social benefits collectively serving to producers, consumers and global society.

But with all these benefits there are always environmental risks associated because by inserting genes from organisms which have never been consumed as food, new proteins or metabolic pathways are introduced into the human and animal food chains or sometimes inserted genes may fail to work or express other unpredicted behavior (Schmidt and Heslop-Harrison, 1998). Concerns and risks studied yet as a result of GM crop consumption are allergic reactions and other health effects, threats to wildlife as horizontal gene transfer, water and soil contamination, antibiotic resistance from GM crops are discussed in this article below.

Worldwide Commercial Scope of GM Crops

The first commercially large scale production of GM crop was done in 1996 by USA since then many other GM crops have been introduced which have delivered substantial agronomic, economic, environmental and health benefits to farmers and consumers. An 87- fold increase was recorded by developing and industrial countries between 1996 and 2010, for global area of GM crops raising from 1.7 million hectares in 1996 to 148 million hectares in 2010 (Adenle, 2011). Such high adoption rates reflect farmer satisfaction with the products that offer benefits as more convenient and flexible crop management, higher productivity, lower cost of production or net returns per hectare, health benefits, and a healthy environment due to decreased use of conventional pesticides which contributes to a more supportable agriculture.

Major Commercialized Biotech Crops of Top 10 Mega-Biotech Countries

In 2011, Pakistan by producing bt cotton at 2.6 million hectares, is listed 8th in the top 10 ranking of Biotech-Mega Countries which grew over 1 million hectares and the USA continued to be the largest producer of GM crops with their 43% of global market share (Adenle, 2011). And in terms of three dominant Trait of GM crops (virus resistant, herbicide tolerant, pathogen resistant) Herbicide Tolerant Soybean continued to be the dominant biotech crop grown commercially in 11 countries in 2011. According ot the table represents the major commercial biotech crops of 10 Mega-biotech countries.

Procedure of Developing Genetically Modified (GM) Crops

Genetic modifications are techniques used to manipulate the genetic makeup of an organism by inserting specific useful genes. A gene is an arrangement of nucleotides on DNA and contains data that encodes a specific trait/attribute. All life forms have DNA (genes).Genes are units of legacy that are transferred from one generation to the next and give directions to development and functions of the living beings. Crops that are produced through genetic alteration are known to as genetically modified (GM) crops, transgenic yields or genetically engineered (GE) crops.

Isolation of gene of interest

Gene of interest is recognized and isolated by knowing about its specific function, structure and location on chromosome (Rao *et al*., 2009).

Insertion of gene into a transfer vector

In plants generally, plasmid isolated from naturally occurring soil bacterium (*Agrobacterium tumefaciens*) is used for the transfer of genes. Recombinant DNA technology is used to insert targeted gene into plasmids (Muzaffar *et al*., 2015).

Plant transformation

The transferred A. tumefaciens cells containing the plasmid with the desired genes are blended with plant cells or cut bits of plants, for example, leaves or stems (explants). A portion of the cells take up a bit of the plasmid known as the T-DNA (exchanged DNA). The A. tumefaciens inserts the wanted genes into one of the plant's chromosomes to GM (or transgenic) cells. The other most normally utilized system to exchange DNA is particle bombardment (gene gun method) where small particles covered with DNA atoms are bombarded by gun into the cell (Rao, *et al*., 2013).

Selection of the modified plant cells

After transformation, different techniques are utilized to screen the transferred and not transferred plant cells. Regularly, selectable marker genes such as anti-microbial or herbicide resistance are utilized to support the development of the changed cells in respect to the non-changed cells. For this strategy, genes responsible of resistance are inserted into the vector and exchanged alongside the gene of interest in to the plant cells. At the point when the cells are exposed to the microbes or herbicide, just the transferred cells (containing and communicating the selectable marker genes) will survive. By using tissue culture methods these transferred cells are regenerated into whole plant (Harlander, 2002).

Regeneration into whole plant via Tissue Culture

Explants (plant parts/cells) are transferred onto the media containing supplements that prompt development of the cells into different plant parts to shape entire plantlets. Once the plantlets are attached they are exchanged to pots and kept under controlled ecological conditions (Bajwa *et al*., 2013).

Verification of transformation and characterization of the inserted DNA fragment

Check of plant transformation includes that the inserted genes has been incorporated and functioning normally. Tests are done to focus the number of copies inserted, whether the copies are in place, and whether the insertion does not interfere with different genes to bring about unintended impacts. Gene expression tests are done to verify the functions of inserted gene (Rao, *et al*., 2013)

Testing of plant performance

It is done first in the nursery or screen house to figure out if the modified plant has the desired characteristics and does not have any new undesirable genes. Those that perform well are planted into the field for further testing. In the field, the plants are first developed and kept in field trials to test whether the innovation meets expectations (if the plants express the desired characteristics) in the open environment. In the event that the innovation lives up to expectations then the plants are tried in multi-area field trials to build up whether the product performs well in distinctive natural conditions. On the off chance that the GM harvest breezes through every one of the tests, it might then be considered for commercialization (Vasil, 2003).

Safety Analysis of GM Crops

There are numerous ways for the identification of accidental changes in GM Foods‘ composition which may arise due to the genetic changes i.e. comparative analysis (chemical) GM and non GM foods. These ways of identification of alterations also include profiling methods i.e. DNA/RNA microarrays, Metabolomics and Proteomics. It is evident that these profiling methods are very much useful but still studies on sensitivity, specificity and substantiation are needed. Furthermore, bioinformatics studies will be very useful for the fruitful use of these profiling methods to analyze safety of genetically modified (GM) foods in which we study and compare different linked databases which may cover all the information significant for profiling accompanied with transformations in stages of development and environmental circumstances (Cressman and Ladics, 2009).

The use of profiling methods for safety analysis of GM foods may produce related information about changes in gene expression and linked metabolic outcomes due to the genetic alterations. A neutral comparison between GM and non-GM organisms may provide us with changes observed at different integration stages of cells and the tissues. But there is a restriction in applying these profiling methods that is the production of a huge amount of data to analyze specific genetically modified generations and natural complications in producing a significant explanation. The absence of up-to-date associated databases that contains information of profiles‘ variations linked with related developmental steps and environmental circumstances is another problem. The ability of profiling techniques to identify unwanted effects linked with genetic alterations is apparent but in order to ensure sensitivity and specificity, more investigation is required to discuss their importance for the safety analysis of GM foods (Fiehn *et al*., 2000).

Environmental Risks of GM Crops

GM crops are being produced on mass scale in spite of the debate on impact of GM crops on environment and human health. (Yaqoob *et al*., 2016). (Researchers found that on the average, the production of GM crops has reduced the use of pesticides by 37%, yield of crops has been increased by 22% and farmers are being benefited by GM crops 68%. Despite of all these facts, GM crops pose environmental risks (Klümper and Qaim, 2014). Genetic modification increases the organism‘s ability to become invasive in environment, indigenous species become extinct and this causes severe consequences to biodiversity (Bruening and Lyons, 2000). They can cause production of new weedy species that may develop resistance against viruses, bacteria and fungi. (Bauer, 2005). Genetically modified crop can itself become a weed and can be a serious threat for plant. Moreover the toxin producing plants can be harmful for insects like butterflies and moth and can accumulate in other insects. GM crops can have adverse ecological effects and also their nutritional content can have negative effect on human health. (Beddington, 2010).

Health Hazards of Glyphosate and Roundup Tolerant Crops

Over 80% of genetically modified crops are herbicide tolerant. Soya bean is the most widely herbicide tolerant crop being produced these days. The other most widely grown GM crop that is herbicide tolerant is Roundup Ready soy that is modified to tolerate roundup herbicide of which active ingredient‖ is glyphosate. Farmers freely spray the herbicide in the fields; all life is killed except crops. GM RR crops store the glyphosate in their tissues, but sometimes it is broken down into a compound named aminomethylphosphonic acid AMPA, which is then eaten by people and animals and both are toxic to health. The demerit of glyphosate tolerant crops is that the use of glyphosate has increased intensively on crops and it is found in water rain and soil as well, that is toxic to human health (Duke and Powles, 2008).The animals fed with GM food crops (soybean, corn) have contained residues of glyphosate in their organs and tissues. This issue was not considered or we can say has neglected in legislation (Chang *et al*., 2011).

Major toxic health effects of Glyphosate

- Glyphosate interferes with cytochrome P450 enzymes. These are the enzymes that help in metabolization of xenobiotics (Latif *et al*. 2015).
- It can cause serum sulphate transport impairment
- It can disrupt biosynthesis of amino acids by gut bacteria.
- Many disorders like obesity, diabetes, depression, heart disease, autism, gastrointestinal disorders are reported due to the intake of glyphosate in western diet. (Lu *et al*. 2015).

Health Issues of Bt Toxin

It was a general concept, that Bt toxin engineered in GM crops only affects the related pests but do not effects mammals and other life forms (Li *et al*. 2007). However, further studies showed that it is also toxic to other life forms. In in vitro studies on human cells, Bt toxins were found to be very toxic to human cells. When high dose of one type of Bt toxin was given to cells, it slowly killed these cells. So it showed that Bt toxins do not effect only pests but it is also harmful for human cells (Mesnage *et al*., 2013).

In vivo studies also showed the harmful effects of Bt crops when tested mice. These harmful effects were

- Toxic effects in small intestine, liver, kidney spleen, pancreas.
- Disturbance in function of digestive system.
- Damage of Male reproductive organ.
- Disturbance in the biochemistry of blood.
- Disturbance of immune system (Finamore, *et al*., 2008)

Overall Environmental Risks of GM Crops

Habitat change: The increase in the production of the genetically modified plants has changed more than half of grass lands and forests into farmlands. The rate of deforestation in Latin America and in Argentina has increased with the increase in production of GM crops after 1997.

Aquatic ecosystem: GM crops effects the aquatic ecosystem by increasing the rate of pollution and introducing nonnative species in aquatic ecosystem. GM crops cause diseases in fishes, and change in the aquatic ecosystem. If some active particle of GM crops enters in the body of fish then it causes a large level of diseases in fishes (Dommelen, 1999).

Resistance: Pests and herbs develop resistance no matters if the plants have been formed by traditional breeding method or by GM technology. A study in US showed that 15 species of weed have developed the resistance against herbicide resistance GM crops. In India, American bollworm developed the resistance against Bt cotton in 2009 and it was the first case seen there. The resistance in the pests causes the formation of superbugs (Smyth and Naseem, 2017).

Invasive Alien species: Invasive alien species are the major cause of the extinction of the other species. GM crops are among one of the reasons that causes the formation of invasive alien species. GM crops themselves become invasive species sometimes because they are the crops having traits, which are new to the existing network of environmental relationships (Pilate *et al*., 2002). GM crops are the cause of formation of invasive alien species because by GM crops resistance in the pests may occur or new pests may form.

Gene transfer: GM crops effects the other species by gene transfer method. In 2001, it was seen that herbicide resistant canola transfer its gene to the nearby grasses, and thus these grasses also become herbicide resistance (Gressel *et al*., 2017). It was also seen that when human being eats GM crops, its genes are also transferred in the bacteria present in intestine of human being thus it is also an alarming effect of GM crops.

Effect on non-targeted species: GM crops also affect the non-targeted species or useful species. For example, it was seen that the herbicide resistance plants kills the young bees also along with its targeted species. GM crops also kill the bacteria and microbes that live in soil. GM crops kill the useful insects which helps in pollination like butterflies and honeybees (Ives *et al*., 2017).

Allergy causing agents: Introduction of genetic material from one plant to the other plant may transfer allergenic materials in plant species. Some proteins cause more allergy reactions and transfer of these proteins can cause severe allergy in organisms taking that protein. So people who get severe allergies should avoid that food.

Conclusion

Genetically modified crops are proved to be useful to overcome the food shortage problems in most of the poor African countries. There are many other benefits of GM crops such as increasing production of agricultural yield and for research purposes but we cannot compromise on the negative aspects of using GM crops in our daily life as these may produce various environmental risks. To use GM crops in daily life, their safety regarding human health must be ensured.

References

Adenle, Ademola, A. (2011). "Global Capture of Crop Biotechnology in Developing World over a Decade." *J Genet Engin. Biotechnol*. 9: 83-95.

Bajwa, Kamran Shehzad, Ahmad Ali Shahid, Abdul Qayyum Rao, Muhammad Sarfraz Kiani, Muhammad Aleem Ashraf, Abdelhafiz Adam Dahab, Allah Bakhsh, Ayesha Latif, Muhammad Azmat Ullah Khan, and Agung Nugroho Puspito. (2013). "Expression of Calotropis Procera Expansin Gene Cpexpa3 Enhances Cotton Fibre Strength." *Aust. J. Crop. Sci.* 7: 206.

Bauer, Martin W. (2005). "Distinguishing Red and Green Biotechnology, Cultivation Effects of the Elite Press." *Int. J. Public Opin. Res*. 17: 63-89.

Beddington, John. (2010). "Food Security: Contributions from Science to a New and Greener Revolution." *Philos. Trans. R. Soc. Lond., B, Biol. Sci.* 365: 61-71.

Bruening, G, and J Lyons. (2000). "The Case of the Flavr Savr Tomato." *Calif. Agric.* 54: 6-7.

Chang, Feng-chih, Matt F Simcik, and Paul D Capel. (2011). "Occurrence and Fate of the Herbicide Glyphosate and Its Degradate Aminomethylphosphonic Acid in the Atmosphere." *Environ. Toxicol. Chem.* 30: 548-55.

Cressman, Robert F, and Gregory Ladics. (2009). "Further Evaluation of the Utility of “Sliding Window” Fasta in Predicting Cross-Reactivity with Allergenic Proteins." *Regul. Toxicol. Phar.* 54: S20-S25.

Dommelen, A van. (1999). "Hazard Identification of Agricultural Biotechnology. Finding Relevant Questions." Utrecht, The Netherlands: International Books.

Duke, Stephen O, and Stephen B, Powles. (2008). "Glyphosate: A Once-in-a-Century Herbicide." *Pest Manag. Sci.* 64: 319-25.

Fiehn, Oliver, Joachim Kopka, Peter Dörmann, Thomas Altmann, Richard N Trethewey, and Lothar Willmitzer. (2000). "Metabolite Profiling for Plant Functional Genomics." *Nature Biotechnol.* 18: 1157-61.

Finamore, Alberto, Marianna Roselli, Serena Britti, Giovanni Monastra, Roberto Ambra, Aida Turrini, and Elena Mengheri. (2008). "Intestinal and Peripheral Immune Response to Mon810 Maize Ingestion in Weaning and Old Mice." *J. Agric. Food Chem.* 56: 11533-39.

Glass, Sara, and Jessica Fanzo. (2017). "Genetic Modification Technology for Nutrition and Improving Diets: An Ethical Perspective." *Curr. Opin. Biotechnol.* 44: 46-51.

Gressel, Jonathan, Aaron J Gassmann, and Micheal DK Owen. (2017). "How Well Will Stacked Transgenic Pest/Herbicide Resistances Delay Pests from Evolving Resistance?". ." *Pest Manag. Sci.* 73: 22-34.

Harlander, Susan K. (2002). "The Evolution of Modern Agriculture and Its Future with Biotechnology." *J. Am. Coll. Nutr.* 21: 161S-65S.

Ives, Anthony R, Cate Paull, Andrew Hulthen, Sharon Downes, David A Andow, Ralph Haygood, Myron P Zalucki, and Nancy A Schellhorn. (2017). "Spatio-Temporal Variation in Landscape Composition May Speed Resistance Evolution of Pests to Bt Crops." *PloS one* 12: e0169167.

Kathage, Jonas, Emilio Rodríguez-Cerezo, and Manuel Gómez-Barbero. (2017). "Providing a Framework for the Analysis of the Cultivation of Genetically Modified Crops: The First Reference Document of the European Gmo Socio-Economics Bureau."

Klümper, Wilhelm, and Matin Qaim. (2014). "A Meta-Analysis of the Impacts of Genetically Modified Crops." PloS one 9: e111629.

Latif, Ayesha, Abdul Qayyum Rao, Muhammad Azmat Ullah Khan, Naila Shahid, Kamran Shehzad Bajwa, Muhammad Aleem Ashraf, Malik Adil Abbas, Muhammad Azam, Ahmad Ali Shahid, and Idrees Ahmad Nasir. (2015). "Herbicide-Resistant Cotton (Gossypium Hirsutum) Plants: An Alternative Way of Manual Weed Removal." *BMC Res. Notes* 8: 453.

Li, HR, LL Buschman, KY Zhu, FN Huang, and B Oppert. (2007). "Resistance to Bacillus Thuringiensis Endotoxins in the European Corn Borer, Ostrinia Nubilalis." *Biopest Int.* 3: 96-107.

Lu, Hang, Katherine A McComas, and John C Besley. (2017). "Messages Promoting Genetic Modification of Crops in the Context of Climate Change: Evidence for Psychological Reactance." *Appetite* 108: 104-16.

Lu, Kun, Ridwan Mahbub, and James G Fox. (2015). "Xenobiotics: Interaction with the Intestinal Microflora." *ILAR J.* 56: 218-27.

Mesnage, R, E Clair, S Gress, C Then, A Székács, and G-E Séralini. (2013). "Cytotoxicity on Human Cells of Cry1ab and Cry1ac Bt Insecticidal Toxins Alone or with a Glyphosate-Based Herbicide." *J. Appl. Toxicol.* 33: 695-99.

Muzaffar, Adnan, Sarfraz Kiani, Muhammad Azmat Ullah Khan, Abdul Qayyum Rao, Arfan Ali, Mudassar Fareed Awan, Adnan Iqbal, Idrees Ahmad Nasir, Ahmad Ali Shahid, and Tayyab Husnain. (2015). "Chloroplast Localization of Cry1ac and Cry2a Protein-an Alternative Way of Insect Control in Cotton." *Biol. Res.* 48: 14.

Pilate, Gilles, Emma Guiney, Karen Holt, Michel Petit-Conil, Catherine Lapierre, Jean-Charles Leplé, Brigitte Pollet, Isabelle Mila, Elizabeth A Webster, and Håkan G Marstorp. (2002). "Field and Pulping Performances of Transgenic Trees with Altered Lignification." *Nature Biotechnol*. 20: 607-12.

Rao, Q, A, K Shahzad Bajwa, A Nugroho Puspito, M Khan, M Adil Abbas, A Bakhsh, AA Shahid, I Ahmad Nasir, and T Husnain. (2013). "Variation in Expression of Phytochrome B Gene in Cotton (Gossypium Hirsutum L.)." *J. Agr. Sci. Tech.* 15: 1033-42.

Rao, Abdul Qayyum, Allah Bakhsh, Sarfraz Kiani, Kamran Shahzad, Ahmad Ali Shahid, Tayyab Husnain, and S Riazuddin. (2009). "The Myth of Plant Transformation." *Biotechnol. Adv.* 27: 753-63.

Schmidt, Thomas, and JS Heslop-Harrison. (1998). "Genomes, Genes and Junk: The Large-Scale Organization of Plant Chromosomes." *Trends Plant. Sci.* 3: 195-99.

Smyth, Stuart, and Anwar Naseem. (2017). "Environmental Sustainability and Biotechnology: Introduction to Agbioforum Special Issue of the 19th Icabr Conference."

Vasil, Indra K. (2003). "The Science and Politics of Plant Biotechnology—a Personal Perspective." *Nature Botechnol.* 21: 849-51.

Yaqoob, Amina, Ahmad Ali Shahid, Tahir Rehman Samiullah, Abdul Qayyum Rao, Muhammad Azmat Ullah Khan, Sana Tahir, Safdar Ali Mirza, and Tayyab Husnain. (2016). "Risk Assessment of Bt Crops on the Non-Target Plant-Associated Insects and Soil Organisms." *J. Sci. Food Agr.* 96: 2613-19.