

Review

Genetically modified organisms (GMOs) in Pakistan

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Biotechnology in the recent years has emerged as a powerful medium for socio-economic development. A wide array of biotechnological techniques is being developed. Genetically modified crops and genetically modified animals are one of such example in which biotechnology has played a key role. Genetically modified organisms (GMOs) are the organisms whose genetic material (DNA) has been modified through unnatural means. This technology is referred to as “modern biotechnology” or “gene technology”, sometimes also “recombinant DNA technology” or the “genetic engineering”. This technology has been used to transfer selected genes from one organism to another organism. This technique has been used around many countries of the world for creating GM crops. However, such developments have resulted in the opening of multiple moral, legal and health issues as discussed in the review. While using such organisms, these issues need to be considered. Whereas considering the advantages, the disadvantages and the downsides are to be realized. Many countries have experienced different challenges while using the genetically modified organism. Currently, USA is considered to be the biggest producer and user of GMOs, whereas the European Union has had few reservations on their use. One common example of GMOs is *Bacillus thuringiensis* (Bt) cotton. The only GM crop commercialized in Pakistan is Bt Cotton. There have been few controversies associated with the use of GMOs in Pakistan which are discussed. This review predominantly considers the effect of GMOs on the agricultural production of the world in general and that of Pakistan in particular, presenting balanced views on its benefits and its certain ill effects. This review also covers the conventions and protocols relating to GMOs and its current status in Pakistan, and also highlights an alternate to GMOs in the form of synthetic biology which helps in the synthesis of new genes without the donor organism.

Key words: GMOs conventions and protocol, advantages and disadvantages of GM, reservations on usage of GMOs, GMOs in Pakistan, synthetic biology, Pakistan.

INTRODUCTION

The genetically modified organisms (GMOs) are those organisms whose genetic material has been modified through unnatural means like fertilization or recombination. GMOs can be of various types like plants, animals or microorganisms (Anonymous, 2009). The recombinant DNA technology also known as genetic engineering has been used to combine DNA molecule from different

sources into one molecule so as to create a desired set of genes (Sarad, 2004). The new gene will contain desirable traits such as pest resistance, herbicide tolerance, drought resistance and enhanced nutritional values. These kind of desired genes are called novel genes.

There has been a substantial increase in the area for GM crops throughout many countries of the world, especially after the first GM crop was commercialized in 1996. According to Figure 1, the area on which GM crops were planted 2007 was about 114 million hectares. This

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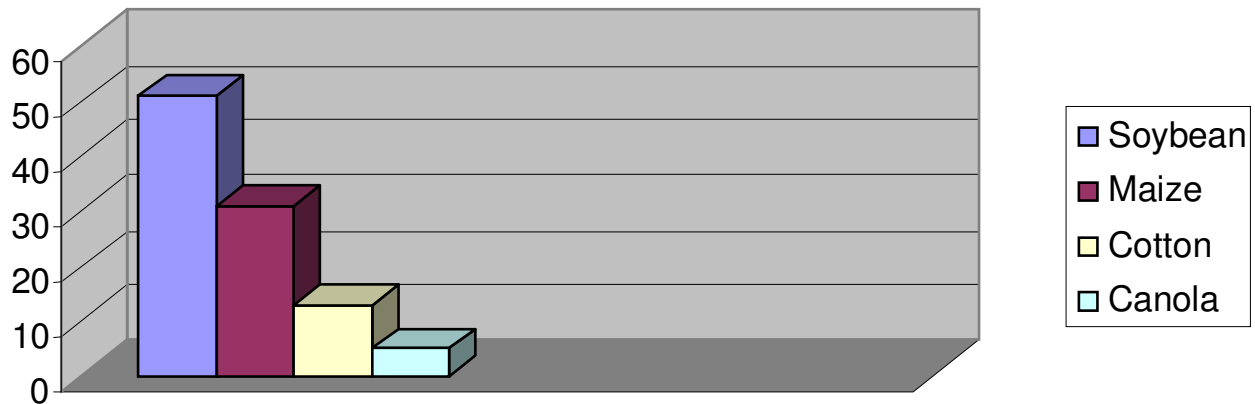


Figure 1. Global production trends of GMOs in different agriculturally important crops planted in 2007, (James, 2007).

area is almost two times to the one which was used to grow GM crops in 2001. Similarly, there has been an increasing trend amongst the farmers to grow GM crops and according to the figures of 2007, the number of farmers who are planting GM crops across the world are about 12 million across 23 various countries (James, 2001). The most noticeable amongst the list of GM growing countries are the United States, followed by countries with emerging economies such as Argentina, Brazil, Canada, India and China. An indication of this statement comes from the fact that these six countries are responsible for 95% of all GM crops worldwide (James, 2007). The countries with emerging economies have witnessed more productivity gains through planting GM crops as these countries were more vulnerable to pests and had a great potential to increase their crop yields (Abdullah et al., 2003).

The rate at which GM crops are being taken up by emerging economies of the world is faster as compared to the developed world. The major traits for which the GM crops were grown in 2007 were herbicide tolerance which accounts for about 63% followed by pest resistance traits which is 18% (James, 2006). The GM crop planted most in 2007 was soybean which was more than 50% of total GM crop area followed by maize about 31%, cotton 13% and canola 5% (James, 2007). Mostly, it has been observed that the GM soybean and canola varieties are grown to get the desired trait of herbicide tolerance, while maize and cotton varieties have been developed for both pest and herbicide resistance. These four crops are responsible for about 99% of all GM crop growing area.

However, people in certain countries are concerned about the impacts of GMOs on health and environment; mainly those which can occur in longer term (Anderson and Jackson, 2005). Owing to these concerns, many countries have passed legislations to protect their consumers and industries from any unwanted impact. Under these regulations, the GM crop or seed that is exported from one country to the other has to be approved. Secondly, the labeling of the GM foods in

many countries is a pre-requisite for the marketing of GM foods and also the testing of GMOs to meet the biosafety standards is mandatory.

REGULATIONS ON GMOs

These regulations include the convention on biological diversity (CBD), Cartagena protocol on biosafety and the international plant protection convention (IPPC).

The convention on biological diversity (CBD)

The convention on biological diversity (CBD) was adopted in Earth Summit Rio de Janeiro in 1992. This convention principally has its focus on conserving the biodiversity; ensure its use in a sustainable manner and equal sharing of genetic resources. Moreover, it also addresses the impact of GMOs respectively.

Cartagena protocol

Keeping the views of impact of GMOs address in convention on biological diversity (CBD), the Cartagena protocol was adopted on the convention on biodiversity in 29th January 2000 and came into force on 11th September 2003. The aim is to ensure the safe handling, transport and use of living modified organisms (LMOs) resulting from modern biotechnology that may have adverse effects on biological diversity, taking into account risks to human health. The protocol set out the advanced agreement procedure for protection and to ensure a safe transfer of living modified organisms across various countries. The governments involved in the imports and exports of these organisms are forced to issue domestic regulations and conditions in the form of advance notification for allowing GM product trade. The article 11 of the protocol stresses on ensuring the documentation

for import and export of GMOs. If any country (exporter/importer) feels that these organisms may harm human health and environment, they are allowed to refuse its entry to their country. In addition, this protocol also declares in article 18 that developing country contacting party, or party which lack domestic frame work able to declare by same as decisions on import of GMOs for direct use as food, feed or processing will be followed by risk assessment. Another condition stated in the protocol suggests that those GM organisms which are used for human food, animal feed or processing require a strict labeling procedure to be followed. However, no such requirement exists for foods which are processed for instance cooking oil or meal (Nielsen and Anderson, 2000).

It was observed that the approval of the Cartagena protocol started few disagreements between various countries (the most obvious was that between USA and the European Union), as the protocol allows to ban the unsafe GM products and puts a condition of labeling of those shipments which are considered to cause any threat to traditional crops and environment. European Union and Asian countries have always had their reservations on the use of GMOs. The US, keeping in view the export losses due to certain requirements by these countries, has approached the World Trade Organization (WTO) saying that the labeling requirements imposed by European Union are hampering the exports of US to a great extent (Anonymous, 2009).

The international plant protection convention (IPPC)

The international plant protection convention is basically a trade convention focused same as the Cartagena protocol like making provision for trade in plants regarding GMOs. The IPPC has also identified potential pest risks such as invasiveness (introduction of new genetic characteristics) and gene flow and effects on non-target organisms. This convention developed international standards for measurement of phytosanitary among its body; basically this standard is mainly focused on addressing the risk posed by plant-pest products of modern biotechnology (Anonymous, 2004). The aim of this convention is to control the trans-boundary movements of pest affecting plants. In addition, IPPC plays an important role in plant diversity conservation and natural resource protection. Although, plant protection law in most developing countries does not exist, it however exists in some other countries although its status is very weak. For example, only sixteen from developing countries followed the international plant protection convention, merely two from Africa (Kenya and South Africa) and none from South or South East Asia (Anonymous, 2002).

Currently, various countries have different stances over the use and commercialization of GM crops. Countries like Canada, China and US have commercialized the

GMOs. On the other hand, the EU and Japan conduct a full environmental impact assessment before the use and commercialization of GM crops. It has been observed that resistance to GM crops is much more in European Union, Japan and Taiwan as compared to US (Grove-White et al., 1998).

BENEFITS OF GMOs

There are certain benefits associated with growing GM crops as compared to the traditional crops. However, it must be kept in mind that biotechnology and its products are only a supplement to traditional breeding and cannot be overemphasized. The various benefits that the countries have observed with the use of GMOs are listed in the succeeding paragraphs.

Pest resistance

Crop losses due to pests mean a huge financial loss to farmers. There is a growing concern amongst the various consumers that crops treated with pesticides are not safe for human use and have certain ill-effects on the human health. GM crops can certainly reduce this trend and chemical pesticides can be reduced to a great extent. *Bt* cotton is an example in this scenario (Anonymous, 2001).

Herbicide tolerance

In certain crops, removing the weeds by physical means such as tilling is not much feasible and so generally it is preferred by the farmers to kill the herbicides through various herbicide sprays, which is both an expensive and a time-consuming activity. Therefore, GM crops are beneficial to this extent in that they can be grown for herbicide tolerant trait and avoid the herbicidal sprays (Anonymous, 1999). Examples include soybean and maize.

Disease resistance

Scientists all across the globe are working to protect the plant from certain viruses, fungi and bacteria that are responsible for many plant diseases. Genetic engineering can be a hope towards making disease free plants (Lynn et al., 2001; Scorza et al., 2001). For example transgenic approaches have been used to Combat Fusarium Head Blight in Wheat and Barley.

Drought tolerance/ salinity tolerance

It has been estimated that the world production will

double by 2050 and as this continues to happen, more land will be utilized for housing as compared to food production. In these circumstances, creating plants that can be resistant and tolerant to drought or high salt content in soil and groundwater will help in increasing the production of crops in the already available area (Zhang and Blumwald, 2001; Wang, 2000). For example, transgenic tomato plants accumulate salt in foliage but not in fruit and the peroxidase activity of desiccation-tolerant loblolly pine somatic embryos have been demonstrated.

Overcoming malnutrition

The third world countries present an ugly picture of malnourishment. The people living in the third world countries especially in Africa mainly rely on single crop for meeting their food requirements and rice is the major food source for these people. However, rice lacks many nutrients which are essential and are required by our body, especially vitamin A. Through the use of genetic engineering, rice can be genetically engineered so as to add additional vitamins and thus many nutrient deficiencies could be overcome. For example, many people suffer from blindness due to vitamin A deficiency, but by using the genetic engineering approach, researchers have succeeded in developing golden rice which contains a high amount of beta-carotene (vitamin A).

Carbon sink and climate change

The issue of global warming and climate change is a big challenge for all humanity in the globe. The deforestation rate, industrial activity, growing transportation and land use changes contribute the great percentage of green house gases in the environment. The use of GM trees especially for carbon sequestration might solve this burning issue (Asante-Owusu, 1999).

DISADVANTAGES OF GMOs

There are a number of risks associated with biotechnology, some of which are mentioned in the succeeding paragraphs.

Allergenicity

While GMOs have many advantages, there are also certain issues and negative effects of GMOs. Allergenicity is one of these major issues. Certain GM foods in USA and Europe have caused serious allergic reactions. To avoid this aspect, there is need for extensive testing of GM foods before declaring them safe for human use (Nordlee et al., 1996).

Unintended harm to other organisms

Another negative aspect linked with the use of GMOs includes unintended harm to other organisms. A previous study concluded that the pollen from Bt corn caused high death rates in monarch butterfly caterpillar (John et al., 1999). These sort of cases need to be further studied before declaring any crop safe for both human and animal use.

Gene transfer to non-target species

Apart from many other concerns, one concern has been that there will be cross breeding between the crop plants engineered for herbicide tolerance and weeds, which can result in the transfer of the herbicide resistance genes from the crops into the weeds. These weeds will become herbicide tolerant as well. The possibility of interbreeding is shown by the defense of farmers against lawsuits filed by Monsanto.

Effect on population and ecosystem

The GM effects on population as well as ecosystem are also been observed. At population stage, species shifting and development of the secondary pest are noticeable, while at ecosystem level the decrease in agriculture biodiversity has been observed due to homogenization.

Interaction with non-alien (natural) species

GM (alien species) crop has capability to produce and grow at faster rate than the non-alien species basically termed as natural species. Their fast maturation fit them for interaction and allow them become alien (invasive means spread into new habitats and causes ecological as well as economic damage). Ultimately, the GM species will interbreed with wild species in the area and may compete with them, resulting in their decline and extinction.

Loss of ecosystem services

Ecosystem services are those ecological processes which operate in vast scale and give the benefits to humankind. These ecosystem services includes goods production (timber, fish), soil generation and its fertility maintenance, detoxification and decomposition of waste and biological control of pest etc. By introducing GM crops into natural ecosystem the natural ecosystem services will be damaged by destroying naturally occurring biological control system, loss of pollination system by destroying the certain vectors which are responsible for pollination process, and also destroy soil organisms

(bacteria and fungi) that are involved in recycling of soil nutrients and play important roles in soil maintenance. The loss of gene diversity badly impacts the farming environment and surrounding species that are playing important roles for humankind in natural manner. In Canada, 73% of cultivated oil seed area was covered with GM, ultimately resulting in the contamination of non-GM seed stocks (Baranger et al., 1995). Therefore, before introducing GM crops, their potential impact must be analyzed (Lovie, 2001).

Impact on agro industry production system

GM impacts on agro industry system in number of ways; for example, environmental pollution, threatening of GM-free production, loss of seed variety and diversity.

Market based dependency and food security

As one of the fastest growing emerging technology, biotechnology may alter the nature, structure and ownership of the food production system and possibly may completely make the farmers dependent on market-based approach. Also, power may come in the hand of some giant firms and they may increase their monopoly over seed production. Moreover, if GM crops may fail to resist altered climatic conditions, the food security threat might be increased rather than decreased in most of the developing countries.

Economic / export loss concerns

The GM crops might be a threat to economic market because of its very lengthy and costly process to bring the GM in the market. In addition, investing giant agro biotech organizations may ensure lucrative return on their investment. New GM varieties and engineering technologies are being patented and will raise the price of new varieties seeds; ultimately small farmers and third world countries like Pakistan will be unable to afford seeds for GM crops, and this would further widen the gap between poor and rich countries (<http://www.monsanto.com/monsanto/gurt/default.htm>). The GM foods also may hinder export business; for example in 1998, the European Union prevented import of bulk shipments of maize coming from USA which led to export loss of \$250 million annually because this shipment contains varieties there were not approved in Europe (Anonymous, 2001).

Religious and ethical values

Biotechnology alters the genetic make of the organisms, for example, animal's genes are placed into plants or

animal's genes are inserted into human. This is considered as unethical and against moral value practices especially in Muslim population.

STATUS OF GMOs IN PAKISTAN

Pakistan is an agriculture based country with more than 47% of its population dependant on agriculture as a means of livelihood. This sector contributes 24% to gross domestic product (GDP). Agriculture alone contributes about 70% of its foreign exchange. Unless it maintains stable growth rates, its economy will suffer immensely. Pakistan is an agricultural supplier that not only meets its requirements but also exports crop to few countries which involves our neighbor Afghanistan, as well as the Middle East and several Central Asian Republics. However, over the recent years, Pakistan is facing some serious challenges on the horizon of which drought, salinity, stress and climate changes are the most important ones. All these issues have raised questions over the food security issues in Pakistan and other parts of the world. The population of Pakistan is about 180 million which is estimated to rise to 240 million by the year 2035. To tackle these challenges, one approach that has been used in the world and to some extent in Pakistan is the genetically modified organisms.

However, there have been a few controversies over the use of GM crops in Pakistan. The only GM crop approved and grown in Pakistan is the Bt cotton mainly grown in the southern Punjab. Pakistan Atomic Energy Commission (PAEC) provided about 40,000.00 kg seed of insect resistant cotton varieties including IR-FH-901", "IR-NIBGE-2", "IR-CIM-448" and "IR-CIM-443" in May 2005, which were grown on about 8,000 acres of land in the year 2005-2006. The outcomes and results were encouraging. PAEC has evaluated the results on the bases of their ability to abide by Bio-safety rules. The regions in which Bt cotton was grown included Bahawalpur, Multan, Muzaffer Garh and Karor Pakka, and the farmers tested these crops against its resistance and susceptibility to different insects high temperature, drought and yield and then compared it with traditional cotton varieties grown in similar areas. There have been few benefits observed by the farmers of these regions and it could be concluded from the results that the GM crops may solve a few issues of Pakistan, such as enhanced production and disease resistance. The use of chemical spray may also be reduced through planting herbicide tolerant and pest resistant crops (<http://www.pakissan.com/english/advisory/biotechnology/first.bt.cotton.grown.in.pakistan.shtml>).

GMOs' status in Pakistan in perspectives of various conventions and protocol

Pakistan has ratified both the convention on biological

diversity in 26th July 1994 and Cartagena protocol in May, 2009. Pakistan has also notified the Pakistan Biosafety rules on 21st April, 2005 in order to get the maximum benefits from the GMO technology but at the same time ensuring the safety of humans and the environment. These rules are responsible to govern the manufacture, import and storage of genetically modified organisms. After the notification of Biosafety Rules, 2005, the Biosafety guidelines were developed which underline the procedures to undertake all related activities. The mechanism of monitoring and implementation of the National Biosafety Guidelines is built on the following three tiers;

- (1) National Biosafety Committee (NBC)
- (2) Technical Advisory Committee (TAC)
- (3) Institutional Biosafety Committee (IBC)

The secretary, Ministry of Environment, is responsible to head the National Biosafety Center and looks after the laboratory work, field trial, commercial release, export, import, sale and purchase of GMOs and their products. All requests of any activity related to GMOs is submitted to relevant IBC which is the monitoring, implementing and regulatory board at the baseline level, then these must be transferred to TAC for assessment on its recommendations, and NBC takes further actions (www.environment.gov.pk).

Pakistan has fulfilled all the documentation procedure at the perspectives of Cartagena protocol. The Ministry of Environment developed the guidelines for GMOs in May 2005 to organize laboratory research, field studies and commercial release of GMOs and their products. All the stakeholders pertaining to academia, research and development (R & D) organizations, private sector, industries and NGOs have participated in formalizing these guidelines. These guidelines were formulated in accordance to the guidelines of Food and Agriculture Organization (FAO), World Health Organization (WHO), United Nations Industrial Development Organization (UNIDO) and United Nations Environment Programme (UNEP). The objective of these guidelines was to avoid any negligence on the part of laboratory workers, researchers and the end users. But unfortunately, Pakistan environmental protection agency has not been able to indulge concerned scientist and researcher for authentication of genetically modified organisms. The set up of the biosafety clearing house is not satisfactory, hence it is very essential to establish strong setup for GMOs' risk assessment. If it does not happen soon, it may result in the loss of the export products in international market. Moreover it may produce species posing great threat.

The international plant protection convention is basically a trade convention focused same as the Cartagena protocol. The aim of this convention is to control the trans-boundary movements of pest affecting plants. Moreover IPPC plays an important role in plant diversity conservation and natural resource protection. Although

plant protection law in most developing countries does not exist, if in some other countries it exists, its status is very weak. For example, only sixteen from developing countries followed the international plant protection convention, merely two from Africa, the Kenya and South Africa, and none of from South or South East Asia. Pakistan is still not signatory or legal binding to International Plant Protection Convention. Therefore, it is necessary that Pakistan bind to legal agreement for the protection of biodiversity and prevent risk form GMOs.

SYNTHETIC BIOLOGY AS AN ALTERNATIVE TO GENETIC ENGINEERING

Synthetic biology has come up as an emerging field of biotechnology which can be defined as the engineering of biology. It basically involves the synthesis of biologically based systems through artificial means. The field of synthetic biology promises a lot of hope and potential in the future. Synthetic biology will allow the designing of biological systems in a systematic way. It is further hoped by the scientists worldwide that this emerging field of synthetic biology will create highly generic potential for use of bio-inspired tools and processes having their applications in industry as well as economy (Isaacs et al., 2003). The basic aim of this emerging field of synthetic biology is to go a step further through synthesizing new biological systems from scratch with added characteristics and properties that are controllable.

Traditional biotechnology vs. synthetic biology

It is a fact that conventional biotechnology has been able to achieve certain milestones, but the developments of these targets have been rather slow and expensive. On the other hand, if we use the approach of synthetic biology, there is hope that the process of research and development will take place at a pace much faster than that to traditional biotechnology (Anonymous, 2005).

Role of synthetic biology in GMO safety

One of the major applications of synthetic biology may be in encoding the genetic information of a transgene in artificial nucleic acids and this might allow for a much safer route to the genetic alteration due to the fact that the presence of the transgene would always be relying on the external supply of artificial nucleic acid precursors. A genetic alteration hence can be removed from a transgenic plant.

Negative views

Some people argue that the emerging field of synthetic

biology may raise certain ethical questions; some others believe it is like praying God. The need will be to define an ethical framework. An encouraging sign in this regard is the fact that the ethical and safety aspects of synthetic biology are already under discussion amongst various scientific circles.

CONCLUSION

The genetically modified organisms can help in food production, drought resistance, climate change mitigation and disease resistance, but in addition it may produce number of threats at gene, individual, population and ecosystem level. They can also have an impact on the agro industry of developing countries. The GMOs can be complementary to the traditional crops but by no means can they replace the traditional crops. The world must ensure that the standards are followed in using the GMOs and are being continuously monitored. The developing countries like Pakistan should ensure strong scientific capacity and research based approach in the field of genetically modified organisms. The Pakistan Environmental Protection Agency should fully concentrate and equip their manpower in growing emerging technology (biotechnology), and they must completely analyze risk assessment before introducing GM from other countries.

Furthermore, Pakistan must concentrate on synthetic biology as an alternative to the emerging field of biotechnology, as it poses least risk as compared to traditional biotechnology. The European Union and USA also promote its expertise in synthetic biology. Therefore, it is need of the hour to promote the research in this area in Pakistan as a powerful replacement to traditional biotechnology. The funding organizations should allocate a good quantity of financial resources to encourage the research on synthetic biology. Apart from this, synthetic biology should be included in the curricula at appropriate level. Training of our scientists in this field is another major aspect that should be immediately taken up.

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