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IMPACT OF TRANSGENIC CROPS ON GLOBAL FOOD SECURITY: A REVIEW

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ABSTRACT

In this review, potential status of the transgenic crops on the basis of previous authentic studies were evaluated through review of literature at Transfermation Lab, Agricultural Biotechnolgy Research Institute, AARI, Faisalabad, Pakistan during the year 2019. Transgenic crops are a great break through in the field of agriculture since 1996. Popularity of transgenic crop is evident as the area under cultivation has been increased many fold in some developed countries i.e. United State, China, Argentina and Brazil etc. These crops have shown the potential to cope with the serious emerging challenge of global food shortage. Changing climate, increasing world population and the unavailability of quality food to the masses are the main reasons of food scarcity among global population. Developing countries are more vulnerable to food security issues. Moreover, in developing countries mineral deficiencies and malnutrition are very common and also severe issues. To deal with these serious issues, researcher's have successfully developed several transgenic crops. Maize has maximum number of approved transgenic variants till now. Pakistan has also approved transgenic cotton for commercial cultivation. Many of the crops like maize, wheat, rice, barley, sorghum and many others are targeted to enhance the minerals, iron, zinc, pro-vitamin A contents etc. Despite of potential applications, several issues are also associated with transgenic crops making them risky for soil ecosystems, natural food web and human health. In this review paper, intrusion of transgenic crop in agriculture, role in food security, potential risk related to ecology and human health and public perception about transgenic crop in discussing in depth in light of literature published up to date.

KEYWORDS: Transgenic crops; food security; mal-nutrition; human health; transgenic maize; Pakistan.

INTRODUCTION

Today the global population is facing serious challenges regarding food availability, health, environment and energy. Lives of millions of people rely on crop genetic improvement that is required to deal with the increasing food demand of world population. Limited population resources and fluctuating climate (Cao and Li, 2013). The increasing world demands with respect to food, feed and fiber cannot be addressed through conventional plant breeding strategies because of lengthy process of varietal development and early genetic breakdown due to evolution in insect pest. So, a quick and long lasting technology must be introduced. Biotechnology, as a tool of plant geneticist's has played a vital role in the global food security, peace and prosperity of nations (Raybould and Quemada, 2010). Transgenic crops produced by applying biotechnology advancements can ensure future food security by strengthening a sustainable small farm agriculture industry especially in the developing countries (Leisinger, 1995; Rifkin, 1998). That's why it is very important to study the pros and cons of transgenic crops either these are able to feed our future generations without providing any harmful effect or not.

Genetically improved seed is just only a little part of the world's solution strategy to ensure food security. Such kind of seed must be subjected into specific farming systems; differentiated upon ecological basis and should be evaluated with respect to their environmental, economic and social impacts i.e. the three pillars of sustainable agriculture. Moreover, yield gap must be reduced by good agronomic practices and improved seed (Huang *et al*., 2002). In this review paper, the integration of transgenic crops into agricultural industry throughout the world and their current and future contribution to ensure the sustainable agriculture is discussed along with some of their potential risks related to ecology and human health. Confusions exist among the public about the use of GMO's, that's why the very basic objective of this study is to discover the answer of the question "Transgenic Crops: good or bad?"

Why we need to ensure global food security

The world population is expected to increase from 6.7 to 9 billion by 2050. About 86 million individuals per year are added in the population, especially in the developing countries (Ronald, 2011; Fedoroff, 2015). Nowadays, 815 million people in the developing countries are affected by malnutrition while 1.3 billion people are facing poverty that limit the access of poor people to the food (Godfray *et al*., 2010). In short, in the next 40 years, food demands will be doubled in the developing countries Cooper, 1998; Godfray *et al*., 2010). In order to fulfill that increased demand for food, 50% of the global agricultural production is needed to be increased by 2030.

Impact of climate change on food security

Another major challenge that world would face by 2050 is climate change that would limit the production of major crops like wheat, maize, rice and soybean up to 23%. Major crop prices and their production were analyzed by "The Centre of Development Research, the University of Bonn, Germany" from 1961 to 2013. They reported that by 2030s, a significant reduction of crop production will be observed. This reduction in the production of major crops will be initiated in many countries but this could be clearly examined in all over the world by 2050s. Not only the temperature, but other extreme weather conditions including extreme rainfall or drought could reduce the potential of crops (The Daily Climate, 2017; ISAAA, 2017).

Transgenic crops and food security

The crops varieties whose genome contain one or few well-characterized gene/genes from any species of plants or any other organism are also known as genetically modified crops, that could have significant contribution to global food, feed and fiber security (Jia and Peng, 2002).

In 1999 to 2002, questions were roaming about whether a new, "Double Green Revolution" increased yield attaining environmental sustainability could help to meet food demands in next 20 years? (Serageldin, 1999; James, 2003). The expected answer to these questions is that the transgenic crops could contribute to food security by promoting sustainable agriculture (Rifkin, 1998; ISAAA, 2017). For example, Bt cotton and Bt maize has showed increased production as compared to old conventional varieties i.e. transgenic cotton with an event; MON531 saved the cotton industry in Pakistan (Economic Survey of Pakistan, 2017-2018; ISAAA, 2017).

Status of transgenic crops A brief history

In 1996, first time in the history, the genetically modified (GM) crops were adopted. During initial five years (1996-2000), transgenic crops showed rapid adoption that is a reflection of their significant and multiple benefits recognized and felt by all classes of farmers both in the developing and industrial countries.

Moreover, 25 times uplift was reported in the global area of transgenic crops, during the years of 1996-2000, and 125 million hectares was the aggregated area. In 2001, 52.6 million hectares was the estimated global area of transgenic crops. In 2001, a significant improvement was observed in the acceptance of transgenic crops because it was the first year that the global area under cultivation of transgenic crops had been exceeded to 50 million hectares (Ronald, 2011). It was reported that the world area under cultivation of transgenic crops increased by more than 30 fold and countries cultivating transgenic crops increased from 6 (in 1996) to 13 (in 2001) during 1996-2001 (James, 2003). In 2008, 25 countries including 15 developing countries, 30 genetically engineered crops were reported to be cultivated on around 300 million acres (James, 2009).

Highest adoption rates for transgenic crops in agriculture sector represents grower's satisfaction for the products of this marvelous technology that offer magnificent benefits. The advantages of transgenic crops include higher production and increased net profit per hectare, flexible and easier crop management, safer environment (due to the reduction in the use of pesticides), improved way to control insect pest population and weeds (achievable with transgenic insect resistant and herbicide tolerant Bt crops i.e. transgenic cotton with MON531 event in Pakistan. Economic survey of Pakistan, (2017-2018) and Bt maize (ISAAA, 2017)). Transgenic crops also provide health benefits along with economic benefits to the farmers as compared to the respective conventional crops by utilizing less inputs and production costs (Fedoroff, 2015; ISAAA, 2017).

According to estimation, for the sake of health and economic benefits, 3.5 million farmers started growing transgenic crops (Ronald, 2011). In 2017, approximately 17 million farmers planted 189.8 million hectares in 24 countries, which is equal to an increase of 407 million hectares or 3% from 2016 (ISAAA, 2017).

Transgenic crops: A gift from scientists

Many of the major food feed and fiber crops exhibit reduced yield at above 30°C. So to adapt our existing cops according to constantly increasing and fluctuating temperatures, drought stress in some areas of world while flooding in others, increasing salinity, increasing and altering insect and pathogen threats: are important intentions for the genetic improvements of crops (World Bank, 2007; Gregory *et al*., 2009; Fedoroff, 2015).

Decrease in the CO_2 in the environment can be made possible if we use less insecticides and sprays on the crops. Hence, transgenic crops can also protect and save our environment (Brookes and Barfoot, 2018).

Most of the marginal lands can be made cultivable if we breed the transgenic crops specifically for the marginal lands like for saline soils or rain fed areas and let the specific transgenic crops to grow there (Tilman *et al*., 2011; Odegard and Van, 2014). Thus, the idea of transgenic crops can be applied to cope with stress environments because limited water resources and arable land. In the past 60 years, there is a decrease of 4 fold in the amount of fresh water available per person (United Nations Environment Programme, 2002). From the world map, 50% global wetlands have been vanished. Thus, there is strong need to develop and grow high yielding crops on the same land area with less water utilization (Lobell *et al*., 2008).

For example Drought Gard maize (MON87460) developed by the Monsanto/BASF collaboration was the first commercially released crop that was genetically engineered for drought tolerance, it was developed through the empirical screening approach. The maize plants of this variety contain RNA chaperone that codes for a novel protein. A post-transcriptional mechanism is utilized by the endogenous CSD cold shock domain containing proteins to regulate stress responses (Castiglioni *et al*., 2008). In plants, the advantages of transgenes were initially observed in the improvement of cold tolerance in the transgenic seedlings of Arabidopsis, in which the overexpression of transgenes was observed (McKersie, 2015). Furthermore, it was observed that the CspB expressing transgenic rice plants showed improved growth in terms of greater plant height when they were exposed to heat, cold and water deficits environments. In maize, constitutive over expression have also shown enhanced yield under dry-land conditions. During flowering/late vegetative and grain-filling stages, expression of transgene have also been observed in the positive way. Under normal or well-watered conditions, CspB expression did not show any detrimental effects on plant development, size and productivity. In short, under less water conditions, increase in yield was not associated with a yield penalty in high-yielding conditions (McKersie, 2015).

In 2011, the development of hybrids of commercial maize 'DroughtGard' was initiated after a deregulation application to APHIS of a transgenic maize events. Under normal conditions, growers in the drier regions of the US corn-belt reported more grain (Waltz, 2014). Scientists have also developed transgenic crops for the quality improvement of food i.e. development of Golden rice (Datta *et al*., 2003; Paine *et al*., 2005). Such type of improvements demands diverse and multi-disciplinary approaches that will increase and maintain sustainability of agriculture industry.

Trends in GM crop approval (1996-2017)

In 2014, it was reported that many countries issued approval of GM crops for food, feed and cultivation. But a slight reduction was reported in 2017, as 18 countries issued approvals of GM crops while in 2014 total 22 countries were involved in the GM crop approval. In 2017, these countries issued 176 approvals. In 2017, United States issued only 6 individual events approvals, although USA is among the leading countries in GM crop approvals but it was their lowest since 2010. Except this, both individual and stacked trait events got approval in other countries (ISAAA, 2017).

The percentage of stacked or pyramided events was 70.8% in 2017. This trend i.e. dominant percentage of stacked events than the individual events began in 2008 and raised in 2013 . This trend represents the fact that farmer's inclination towords biotech events and varieties having more traits with minimum cost and good economical turnover is considered by the technology developers (ISAAA, 2017). Combinations of many individual maize events may lead to production of desired stacked trait event have made the maize crop having highest number of approved events up till now.

As discussed earlier that 176 was the total number of approvals in 2017, out of which 52 were for feed, 101 for food and 23 for cultivation. These approvals involved eight crops and 72 events issued by 18 countries. In 2017, Brazil issued maximum number of approvals. One new insect resistance sugarcane event known as CTB141175/01-A, introduced by Centro de Tecnologia Canavieira, was also issued by Brazil in 2017. South Korea and Malaysia were ranked second for issuing high number of GM crop approvals while USA issued six approvals and Argentina granted three approvals in 2017.

Cotton varieties In Pakistan, in the 48th meeting of Pakistan seed council (PSC), four varieties of insect resistant (IR) cotton that express cry1Ac gene with Mon 531 event were permitted in March 2017 for commercial cultivation. In 2017, both public and private sectors institutions made insect resistant cotton hybrids and varieties. These hybrids and varieties express single and double gene(s) like cry1Ac or pyramided/ stacked cry1Ac and cry2A genes but these varieties and hybrids face problems by NBC in the provision of commercialization certificates. As compared to the already cultivated insect resistant varieties, many of these insect resistant hybrids and varieties of cotton showed more ginning out percentage, better spinning performance and good fiber qualities (Khan *et al*., 2017).

IR NIBGE-4 and IR NIBGE-6 developed by NIBGE (National Institute of Biotechnology and Genetic

Engineering), Faisalabad, Pakistan; IR CIM-600 and IR CYTO-177 by CCRI (Central Cotton Research Institute), Multan, Pakistan and TARZEN-3 by M/s Four Brothers Group of Pakistan, Lahore are considered as the most important and prominent insect resistant (IR) cotton varieties (ISAAA, 2017).

From 1992 to 2017, total 4,133 approvals scattered among 498 events covering 29 crops has been issued in 40 countries including 28 European countries (counted as one). These 40 countries issued 1,995 food approvals, 1,338 feed and 800 cultivation approvals (ISAAA, 2017).

Success rate of transgenic crops

On the 22nd year of transgenic / GM crop commercialization, transgenic crops were grown by 24 countries on 189.8 million hectares. These transgenic crops have economically important traits like herbicide tolerance, insect resistance disease resistance, product quality (for example modified fatty acid/oil content, anti-allergy, delayed fruit softening etc.) and pollination control (ISAAA, 2017).

In 2017, industrial countries grew 47% while developing countries grew 53% of the world transgenic area. On the map of world transgenic crop area, soybeans occupied 50% area as it grew on 94.1 million hectares with a 3% uplift from 2016. In 2016-2017, herbicide tolerance was constantly been the most main trait as it covered 47% of the worldwide area in these two years. In 2016, stacked traits were grown on 75.4 million hectares while in 2017, the statistics of stacked traits was 77.7 million hectares that showed an increase of 3% or 2.3 million hectares from the previous year (ISAAA, 2017). In Fig. 1, Global area planted to major transgenic crops is given.

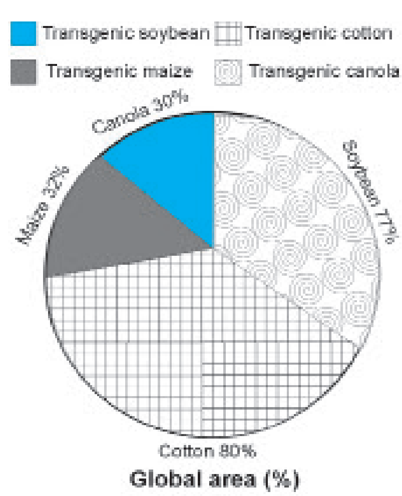


Fig. 1. Global area planted to major trainsgenic crops (ISAAA, 2017)

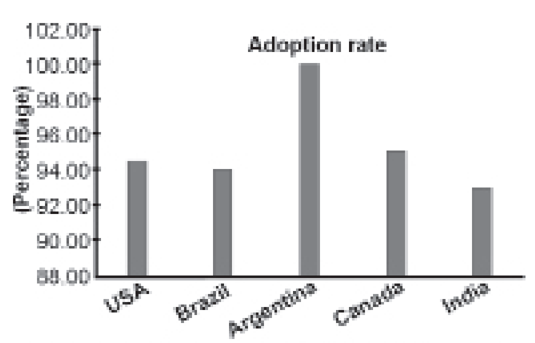
As mentioned before, along with 24 GM planting countries, 43 non-planting countries including 26 European countries have issued the import approval of transgenic crops for food, feed and processing. In short, on the global map, total 67 countries adopted transgenic crops in 2017. From 1996 to 2016, GM planting countries gained a total of US$186.1 billion economic benefits. In 2017, the total economic gain for industrial countries was US$8.2 billion while US$10 billion for developing countries. Economic benefits gained by GM crops planting countries (1996-2016) are enlisted Table 1.

Table1. Economic benefits manifested by GM crops planting countries, 1996-2016 (ISAAA, 2017)

Country Name	Economic Benefits (US$)
USA	US$80.3 billion (highest gain)
Argentina	US$23.6 billion
India	US$21.1 billion
Brazil	US$19.8 billion
China	US$19.6 billion
Canada	US$8 billion
Other countries	US$13.6 billion

In 2017, US$17.2 billion was estimated as the global market value of transgenic crop seeds (ISAAA, 2017). In the global value of transgenic seed market two industry sources would be able to generate an uplift of 8.3% by the end of 2022 to 10.5% by the end of 2025. These huge economic benefits can be produced in the seed market if global plantation of transgenic crops remains continuous.

Slight reduction in the global transgenic crop area in 2015 was reported due to the low product price. James (2015), predicted that this decrease would revert when the global crop (commodity) prices reverse back to higher levels. This prediction proved its worth as in 2017, consistent increase in world transgenic crop area of 3% was reported. In 2017, the average adoption rate of transgenic crops in the top five GM crop planting countries reached close to the saturation point as listed in the graph 1 below.



Graph. 1. Adoption rates of GM crops in top five GM planting countries.

In 2017, favorable market price of cotton became a reason of uplift in the transgenic IR (insect resistance) cotton area in transgenic cotton-growing countries i.e. India, Pakistan, Mexico and Sudan. In these countries, adoption rate of transgenic cotton could be increased by the new GM/transgenic varieties of cotton containing resistance to other diseases and insect pests.

Situation of transgenic/GM crops in Pakistan

In Pakistan, the area cultivated to GM/transgenic cotton was increased from 2.9 million to 3 million hectares i.e. 100,000 hectares in 2017-2018. In 2017, the cotton production was 14.04 million bales and it remained almost at the same figure in 2018. In 2017, transgenic cotton area touched the all-time highest figure of 3 million hectares that is 96% of total cultivated area of cotton in Pakistan (ISAAA, 2017). This prominent increase in insect resistant cotton area became possible due to following reasons:

- Issuance of a healthy support package for farmers which included subsidy on fertilizers.
- By decreasing rate of interest on loans, and many other plans were announced in the 2017-2018 budget by the Government.
- Training of farmers to manage the diseases of cotton like leaf burning syndrome and pink bollworm

In 2017, Pakistan also produced 6.13 million tons of maize that is equal to an increase of 16.3% from last year's production (5.27 million tons). This was the highest maize production ever in the history of Pakistan. In 2017-2018, Pakistan got success in the conducting many demonstrations of transgenic/GM maize hybrids in farmer's fields to show its performance to farmers. In 2016, NBC (National Biosafety Committee) of the MOCC (Ministry of Climate Change) officially approved single and stacked/pyramided HT/IR (Bt) maize affirming herbicide tolerance and insect resistance traits for commercial cultivation. Federal Seed Certification and Registration Committee, Ministry of National Food Security and Research conducted the field performance trials of HT/IR hybrids of maize in 2017, as an element of regulatory requirement for the registration of a variety. Dupont Pioneer and Monsanto Pakistan developed HT/IR maize that would be grown by the maize farmers of Pakistan in the autumn growing season for the first time .

Transgenic cereals

Transgenic Rice (*Oryza sativa*)

Rice is counted among the most important food crops on the global map and statistically proved as a primary food source for more than 50% of the world's population (Garg *et al*., 2018). Around the globe, China is ranked as the largest producer and consumer of rice; approximately rice is grown on 20% of cultivated land of China (Chen *et al*., 2011). In the development of IR (insect resistant) transgenic lines of rice, China is a leading country (Li *et al*., 2014a). From the bacterium "*Bacillus thuringiensis* (Bt)", a lot of rice lines have been developed that express insecticidal genes. These lines require lesser amount of pesticides and give enhanced rice production (Chen *et al*., 2011). That's why when we talk about global status of rice especially transgenic rice, china cannot be neglected. By 2030, a total of 200 million kg of rice is needed to produce to feed the continuously increasing population of China (Chen *et al*., 2011).

Insect pests especially stem borers are considered as one of the prominent factors while we have a glance on multiple constraints to rice production (Sheng *et al*., 2003; Wang *et al*., 2014). To eradicate this issue, chemical insecticides are applied in a huge amount every year which is resulted in a number of problems. These problems include development of resistance in pests against insecticides, Water, air and soil pollution and food contamination (Huang *et al*., 2001). IRGM (insect resistant GM) crops i.e. Bt cotton and Bt maize cultivation can decrease the amount of pesticides used, hence, reducing the harmful environmental effects of pesticides to these crops (Brookes and Barfoot, 2013). So it can be concluded that a good substitute for pest control is the development of insect resistant transgenic rice that express Bt insecticidal proteins (Chen *et al*., 2011).

Some rice lines possess two insecticidal genes i.e. cry1Ab/Vip3H in the G6H line and cry1Ab and cowpea trypsin inhibitor (CpTI) in the MSA or MSB lines (Chen *et al*., 2006; Akhtar and Ye, 2012). Furthermore, some of the lines of Bt rice possess stacked transgenes i.e. for herbicide tolerance, bar gene (Yao *et al*., 2002) and for disease resistance, xa21 gene is present in some rice lines (Wang *et al*., 2002a). In the laboratory and field trials, a lot of lines of Bt rice had shown high resistance to target pests (Tu *et al*., 2000; Tang *et al*., 2006; Cohen *et al*., 2008; Han *et al*., 2011; Sui *et al*., 2011; Zhang *et al*., 2011a; Zheng *et al*., 2011; Wang *et al*., 2014).

Success stories of transgenic rice

To combat with the world challenge of under-nutrition like vitamin deficiency in poor population, transgenic rice has been targeted (Garg *et al*., 2018). Golden rice is an effective and good source of Provitamin A i.e. beta-carotene and is a prominent breakthrough to meet the vitamin deficiency. Golden rice contains PSY and carotene desaturase encoding genes that help to decrease the disease burden (Datta *et al*., 2003; Paine *et al*., 2005).

Expression of genes in rice that encode for transporter OsIRT1 (Lee and An, 2009), nicotianamine synthase 1 (OsNAS1) and 2 (OsNAS2) (Zheng *et al*., 2010; Lee *et al*., 2012; Trijatmiko *et al*., 2016) and soybean ferritin (Trijatmiko *et al*., 2016) have been done to enhance the iron contents in rice to meet the severe challenge of iron deficiency anemia, around the globe i.e. in Pakistan, almost 33% children are suffering from iron deficiency . Introduction of multiple genes that are associated with iron content in rice have also been used to produce transgenic bio-fortified rice (Masuda *et al*., 2012; Masuda *et al*., 2013). In rice, decrease in phytic acid which is an anti-nutrient compound has helped the scientists to improve iron bioavailability in rice (Hurrell and Egli, 2010). Overexpression of OsIRT1 was also associated with the elevated zinc content in transgenic rice (Lee and An, 2009). Overexpression of aminodeoxychorismate synthase and GTPCHI (Arabidopsis GTP-cyclohydrolase I) coding genes have helped to uplift 150X the folate content in rice (Blancquaert *et al*., 2015), as vitamin B9 (folic acid) is very necessary for anemia and normal pregnancy (Bibbins *et al*., 2017).

In rice, essential amino acid content that express *E.coli* aspartate aminotransferase (Zhou *et al*., 2009) and soybean glycinin bacterial aspartate kinase, DHPS (dihydrodipicolinate synthase) (Yang *et al*., 2016) has been targeted to improve the quality protein. In rice expression of maize C1 and R-S regulatory genes (Shin *et al*., 2006); CHS (chalcone synthase) and phenylalanine ammonia lyase genes (Ogo *et al*., 2013) is used to increase the flavonoids content that are associated with antioxidant activity (Table II).

In rice grains expression of lactoferrin (functional milk protein of human) has helped us to produce a baby food and infant formula in which value added, cereal based ingredients can be added (Lee *et al*., 2012).

Transgenic wheat (*Triticum aestivum*)

On the global map, wheat is counted among the most widely grown staple food crops. Scientists are trying to secure global food through wheat by combating with the iron, vitamin A and quality protein deficiency challenges (Garg *et al*., 2018). In wheat, expression of TaFer1-A gene from wheat (Borg *et al*., 2012) and ferritin gene from soybean (Xiaoyan *et al*., 2012) are being utilized to increase the iron content. Expression of CrtB, CrtI i.e. bacterial PSY and carotene desaturase genes has helps to increase the Pro-vitamin A content in wheat (Cong *et al*., 2009; Wang *et al*., 2014) (Table 2).

In wheat, expression of C1, B-peru (maize regulatory genes) that plays a significant role in the production of anthocyanin, has helped to increase the antioxidant activity (Doshi *et al*., 2006). Amaranthus albumin gene (ama 1) increases the protein content of wheat grains like essential amino acids methionine, tyrosine, lysine and cysteine (Tamas *et al*., 2009). Silencing gene that encodes for SBE is used to increase the amylose starch (resistant and less digestible starch), that can fight with the obesity and over-nutrition type issues (Sestili *et al*., 2010).

Transgenic maize (*Zea mays*)

Maize is the 3rd most grown staple food crops in the world especially in the developing countries (Sultana *et al*., 2019). Through genetic engineering, maize genome has been targeted for minerals, vitamins, anti-nutrient compounds and quality protein (Garg *et al*., 2018; Sultana *et al*., 2019).

In development of immune cells, cardiovascular function and iron utilization, vitamin C (a water soluble antioxidant) plays a vital role (Levine *et al*., 1995). Expression of DHAR (dehydroascorbate reductase) helps in the recycling of vitamin C (ascorbic acid) to reduced form, hence increasing its content in maize up to 100X (Chen *et al*., 2006). Expression of bacterial crtB (Aluru *et al*., 2008) and multiple carotenogenic genes (Khush *et al*., 2012; Decourcelle *et al*., 2015) has made an enriched endosperm of maize with carotenoids (pro-vitamin A).

In corn, overexpression of HGGT (homogentistic acid geranylgerany1 transferase) has helped to enhance the Vitamin E and its analog that are potent antioxidants-associated with good human health i.e. tocopherol and tocotrienol (Cahoon *et al*., 2003). In 2009, engineered three different and distinct metabolic pathways to enhance 6X ascorbate, 169X beta-carotene and 2X folate than their normal amounts in the plant body and develop multivitamin maize (Naqvi *et al*., 2009).

Expression of *Aspergillus niger* phyA2 (Chen *et al*., 2008) and soybean ferritin (Aluru *et al*., 2011) has helped the scientists to enhance the bioavailability of iron. Furthermore, by silencing the expression of ATP binding cassette transporter and protein that is associated with multidrug resistance, scientists enhance the iron bioavailability (Shi *et al*., 2007).

As less amount of essential amino acids i.e. lysine and tryptophan cause the poor nutritional quality of zeins (major seed storage proteins of corn), so their genetic transformation is required to increase their level in corn. In corn, single bi-functional expression/silencing transgene cassette (Frizzi *et al*., 2008) and sb401 expression from potato (Tang *et al*., 2013) has enhanced the lysine content. In Mexico and Japan, Monsanto released Mavrea™YieldGard Maize variety that is enriched with lysine. Moreover, in Columbia, Australia, Canada, Mexico, Japan, Taiwan, USA and New Zealand, Renessen LLC (Netherland) has released a lysine enriched corn variety known as Mavera™ Maize (LY038). Some success stories of transgenic events in major cereal crops(Table 2).

Potential risks associated with transgenic crops

The potential negative essence of transgenic crops on environmental safety and majorly on human health has been paved the way of a very strong debate over transgenic crops. We can summarize here the four major reasons that create the confusion among consumers:

Scientific community does not get success in explaining the biological processes and techniques involved in the production of transgenic crops in front of lay man.

Transgenic foods are not properly disseminated among the consumers.

Table 2. Transgenic events in major cereal crops

Research object	Status	Variety	References
Transgenic Cereals			
Rice			
Beta-carotene	Research		Data *et al*., 2003; Paine *et al*., 2005
Vitamin B9 (Folate)	Research		Storozhenko *et al*., 2007; Blancquaert *et al*., 2015
Iron	Research		Lee and An, 2009; Zheng *et al*., 2010; Lee *et al*., 2012; Musada *et al*., 2012; Musada *et al*., 2013 and Trijatmiko *et al*., 2016
Phytic acid	Research		Hurell and Egli, 2010
Zinc	Research		Musada *et al*., 2008; Lee and An, 2009 and Bibbins *et al*., 2017
Folate content	Research		Blancquaert *et al*., 2015 and Bibbins *et al*., 2017
High amino acids and protein content	Research		Lee *et al*., 2003; Zhou *et al*., 2009 and Yang *et al*., 2016
Flavonoids and anti-oxidants	Research		Ogo *et al*., 2013
Wheat			
Iron	Research		Borg *et al*., 2012; Xiaoyan *et al*., 2012
Provitamin A carotenoids	Research		Cong *et al*., 2009 and Wang *et al*., 2014
Anthocyanin	Research		Doshi *et al*., 2006
Amino acid composition	Research		Tamas *et al*., 2009
Amylose content	Research		Sestili *et al*., 2010
Maize			
Vitamin C	Research		Levine *et al*., 1995 and Chen *et al*., 2003
Provitamin A carotenoids	Research		Aluru *et al*., 2008 and Decourcelle *et al*., 2015
Vitamin E	Research		Cahoon *et al*., 2003
Multivitamin	Research		Naqvi *et al*., 2009
Iron bioavailability (Phytase, ferritin)	Research		Shi *et al*., 2007; Aluru *et al*., 2011 and Chen *et al*., 2011
Lysine Lysine and tryptophan Methionine	Research		Frizzi *et al*., 2008 and Tang *et al*., 2013
Lysine	Released	Marvera™ YieldGard Maize (Maxico, Japan) Mavera™ Maize (LY038) (Japan, Columbia, Mexico, Australia, Taiwan, Canada, New Zealand, USA)	Monsanto Renessen LLC (Netherland)

Anxiety among consumer related to the evaluation of transgenic crops (Gibson *et al.,* 2013; Baulcombe *et al*., 2014).

Furthermore, food safety, ecological issues, biosafety regulations, farmer's attitude towards adoption of GM crops and of course, public acceptance of these crops are the major concerns that directly associate with the GM crop commercialization (Li *et al*., 2014a).

Internationally, proper biosafety regulations have been followed for the development of GM/transgenic crops. Laboratory research, food and environmental safety, production, processing, labelling, marketing including export and import of GMOs and GMO-derived products, in short all the factors that are associated with the GMOs have been demonstrated in these regulations. Here we discuss some impacts of transgenic crops on our environment, human health and food safety. Figure 2 is representing the potential Risks of GM Crops.

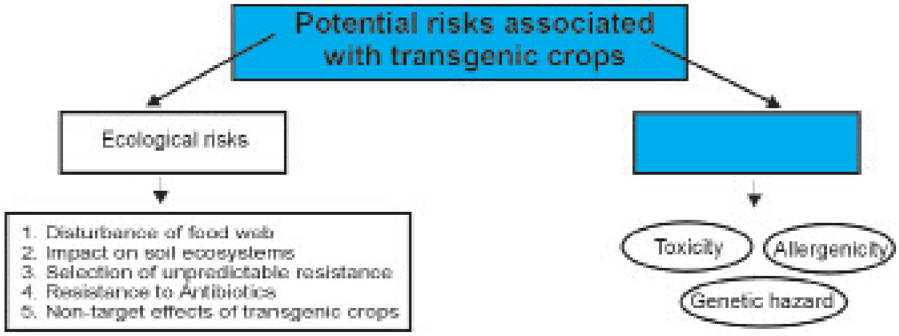


Fig. 2. Potential risks of transgenic crops.

Ecological risks associated with transgenic crops

Disturbance in the food web

The engineered plants can shift the insect population from known to unknown species. Insect resistant crops have the potential to decrease the major pest type while enhancing the population of minor pests. This shift and phenomenon might cause the disturbance of the entire food web i.e. new species of insects will cause the existence of new predators and this will go on until the top most level of the food chain reaches (Bawa and Anilakumar, 2013). Other perspective of this disruption is that the remains of insect or herbicide resistant crops might blow adverse influence on the micro-organisms present in the soil like fungi and bacteria (Snow and Palma, 1997).

Impact on soil ecosystems

Transgenic plants produce Cry proteins that are accumulated in the agricultural ecosystems when we cultivate the GM crops in the soil. Hence residues of transgenic crops are incorporated in the soil as litter or by tillage. This aspect is very important to consider in the environmental risk assessment of Bt crops as the above mentioned phenomenon could interfere in the biological cycle and processes and could also affect non-target sensitive organisms badly (Head *et al*., 2002; Giovannetti *et al*., 2005 and Li *et al*., 2007b). For example, In 2007, found in their experiment that under aerobic conditions, Cry1Ab proteins with a half-life ranging from 19.6 to 41.3 days, from Bt rice crop was rapidly degraded in the paddy soils. Under flooded environmental conditions, degradation of Cry1Ab protein was distinctly extended to 45.9-141 days (Wang *et al*., 2007).

Selection of unpredictable resistance

Now-a-days, production of pest resistant or herbicide resistant crops are two major desired properties of transgenic plants for scientists. Insect resistant transgenic crops express insecticidal crystal proteins (CRY). *Bacillus thuringiensis* (Bt), a soil bacterium produces these CRY proteins. In the herbicide resistant plants express that enzymes (primarily glyphosate Roundup™) which protects against harmful herbicides by degrading the herbicide. The strategy used by us is clever but can these strategies, out-fox nature, in her ineluctable and natural process for the selection of better adapted crop species? What if healthier insects and weeds evolve? After few years, weeds and insects will evolve them naturally to respond the man-created pressures on their habitats to nullify our attempt to get rid of them (Bawa and Anilakumar, 2013).

Resistance to antibiotics

Antibiotics are commonly used in the genetic modification of plants and other organisms i.e. as a selection marker to successfully differentiate the transformed bacteria from that bacteria in which foreign gene/s did not get place to take hold. Thus, we can understand well that this process of making transgenic crops contains a severe risk of transferring antibiotic resistance genes in the bacteria consisting of microflora of animal and human gastrointestinal tracts. This situation is even more adverse in case of pathogenic bacteria harbored by GM food consumer, because bacteria are capable to retain the genes that protect them from antibiotics by horizontal transfer among species (Ricroch *et al*., 2011; Ray *et al*., 2012; Gilbert, 2013).

Non-target effects of GM crops

Transgenic crops have the ability to affect no-target organisms in a bad way, especially the IR transgenic rice do it very well. To achieve a sustainable agricultural ecosystem, natural enemies of pest arthropod are very important and of particular interest (Romeis *et al*., 2006; Li *et al*., 2013, 2014b, c and Zhang *at al.,* 2014). In confined conditions and considering worst case, laboratory experiments are performed such type of assessments (Garcia-Alonso *et al*., 2006; Romeis *et al*., 2008, 2011 and Li *et al*., 2014d). If laboratory experimentation goes fruitless, there is no need to perform semi-field or open field experiments (Romeis *et al*., 2008; Yu *et al*., 2011). But as mentioned in international biosafety rules and regulations and GMO risk assessment guidelines, insect resistant transgenic crops require proper field studies to check their non-target effects.

Health risks concerned with transgenic foods

Proteins expressed by the inserted gene/s, possible disturbance in the natural genomic sequence of transgenic organism, pleiotropic or secondary effects of products generated by the expression of inserted gene cause the health issues like allergenicity, toxicity and genetic hazards. These are three major health issues associated with transgenic foods (Bawa and Anilakumar, 2013).

Allergy can be caused by a transgenic plant if the natural expression level of that plant get some unusual modifications. Production of amino acid (methionine) enriched soybeans is an example of this allegenicity. A gene was isolated from the genome of Brazil nuts and incorporated in the soybean causing increased synthesis of methionine in soybeans. Consequently the consumers that were already allergenically sensitive to the Brazil nuts got allergic reactions on the consumption of GM soybean.

"Starlink" maize was genetically modified by a gene, isolated from *Bacillus thuringiensis.* The purpose of that modification was just to create resistance in maize against certain insects. But the incorporated gene encodes Cry9C protein that has pesticidal characteristics along with an undesired, strong allergenicity. Many consumers got allergic reactions after the consumption of "Starlink" maize. Hence expression of incorporated gene was directly cause food hazard in public in this example (Bravo *et al*., 2007; Sanchis, 2011; Werth *et al*., 2013; Baulcombe *et al*., 2014).

Pleiotropic and secondary effects cannot be easily detected because they disturb the metabolic pathway of other enzymes including toxic ones. Similarly the inserted gene/s can disturb the genomic integrity of the recipient organism, leading to some modification or totally inactivation of endogenous genes. This type of modulation is also not easy to detect that cause allergy.

Food security/safety

Wheat, rice and maize are the major staple food crops of the global population. Hence the food security of these crops is of great concern. In many countries of world, assessments for food security of transgenic crops follow the rule of substantial equivalence, as recommended by the WHO (World Health Organization) and Organization for Economic Cooperation and Development (Bawa and Anilakumar, 2013)

In 2012, in China, transgenic Bt rice lines i.e. Bt Shanyou 63 and Huahui 1 were passed through many comprehensive trials in order to get biosafety certificates for commercial production (Xiao *et al*., 2012). Digestibility, thermal stability, toxicity and allergic nature of Cry proteins that are produced by the Bt crops especially from the Bt rice, anti-nutritional factors and comparisons of the nutritional profile between non-Bt and Bt crop products are counted as the major and prominent problems for food security assessments (He *et al*., 2008; Xiao *et al*., 2012 and Zheng *et al*., 2013). In some studies, it was concluded that both non-Bt and Bt rice products are equally safe as food for humans (Xiao *et al*., 2012; Zheng *et al*., 2013 and Fan *et al*., 2014). In recent years, people started to think and become more curious about the potential chronic effects of transgenic foods. In order to answer these concerns, scientists conducted a long-term research in which transgenic food is given to rats. Sprague Dawley rats were used in that research to check the potential carcinogenicity and toxicity of transgenic rice line named as Huahui 1. A chronic test of 106 weeks was conducted (Fan *et al*., 2014). No statistically significant difference was found between those two classes (Fan *et al*., 2014).

CONCLUSION

From all the above discussion, we concluded that transgenic crops are rapidly occupying the arable land area around the globe. This popularity of transgenic crops among the agriculture producers as well as among the consumers have paved the way for transgenic crops to rule over the existing crop varieties. Many of the transgenic varieties have been approved and provide a helping tool in the food security by supplying enhanced nutrients, vitamins and proteins. But still some issues are there, on the door for resolution i.e. to eradicate negative effects on soil ecosystems, food web and human health. Non-target effects on organisms, marketing issues, import and export regulations etc. Now the answer to the question that either transgenic crops are good or bad cannot be given by simple "Yes or No", rather a comprehensive details about all the aspects of transgenic crops must be given to the lay public to let them understand this splendid technology and to get benefits from this. But we can say that this marvelous technology will feed the world in coming future.

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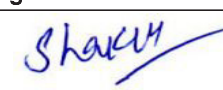
1.	Shakra Jamil	Preparation of outline, prepared writeup	
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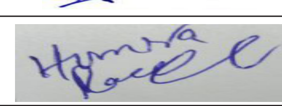
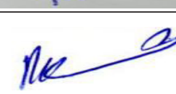
4.	Humera Razzaq	Critically reviewed the article	
5.	Rahil Shahzad	Preparation of outline and perepaed write-up	
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