Environment and Ecology 41 (2A) : 1101—1111, April—June 2023
ISSN 0970-0420

Transgenic Crops : Trends, Techniques and Perspective

Yachna Sood, Manmohan Lal

Received 7 September 2022, Accepted 16 March 2023, Published on 17 May 2023

ABSTRACT

Transgenic technology has announced a new era of plant development, several concerns hindering their widespread acceptance. Genetically modified plants have one or more useful properties, such as weed tolerance, insect resistance, abiotic stress, disease resistance and nutritional development, malnutrition and food insecurity. The adoption of transgenic technology has been shown to increase yields, reduce the use of pesticides and insecticides, reduce CO_2 emissions and reduce crop production costs. However, widespread acceptance of transgenic plants faces roadblocks due to potential toxicity and allergenicity in humans, potential environmental hazards, such as genetic flow, adverse effects on unintended substances, weed emergence and pest resistance. Climate change and the exploration of new agricultural areas have contributed to the acceptance of transgenic plants globally. This review is an overview of advantages, concern and future scope of transgenic plants.

Keywords Transgenic, Resistance, Potential.

INTRODUCTION

Today, the world's population faces serious challenges related to food, health, environment and energy supply. At present, environmental degradation and population growth are the two major problems on planet Earth. Meeting the needs of this growing population is extremely difficult due to the limited agricultural area in the world. Now a days malnutrition is a growing concern in developing countries, leading to various health and social problems, such as mental retardation, weakened immune system and poor health. Development is needed to meet the growing food needs of the world population. Development of genetically modified plants change the lives of millions of people (Cao and Li 2013). Genetic engineering has been used to produce mass insulin, yield improvement, increase tolerance of herbicides and biofortification. The growing global demand for food, feed and fodder cannot be routinely evaluated by conventional crop breeding strategies due to the long process of species development and premature genetic decline due to the emergence of pests. The development of plants adapted to abiotic conditions is very important for food production in many parts of the world today. Expected climate change and diversity, especially extreme climate change and rainfall are expected to make crop development more important in food production Biofortification of plants often means that their production has a higher nutritional value. This can be achieved through traditional breeding or genetic engineering. The difference between biofortification and fortification is that it aims to make plant foods naturally more nutritious, rather than adding nutritious ingredients to food during food processing. So fast and long-lasting technology should be introduced. Variable crops produced through the advancement of biotechnology can ensure food security in the future by strengthening the agricultural industry on small farms especially in developing countries (Lal *et al.*

Yachna Sood[1]*, Manmohan Lal[2]
[1]Associate Professor*, [2]Assistant Professor
Department of UIAS, Chandigarh University, Gharuan 140113, Mohali, India
Email: gupta.yachna23@gmail.com
*Corresponding author

2022). Transgenic plants are plants that use genetic engineering processes to introduce one or more genes into the genome. The aim is to introduce features of plants that do not occur naturally among species. Mutable plants contain genes. The gene sequence inserted is called a transgene, either derived from an unrelated tree or a completely different species. The purpose is to insert the gene into the plant, to make it as useful and efficient as possible. This process offers benefits such as improved shelf life, higher yields, improved quality, stronger insects, heat resistance, cold and drought, by combating various biotic and abiotic pressures (Zhao *et al.* 2021). Transgenic plant enhances the nutrients in the plant called Biofortification of plants often means that their product has a high amount of healthy nutrients. Biofortification can be achieved through the use of genetic engineering. It aims to make naturally more nutritious food, rather than adding ingredients to food during food preparation. There are several examples of transgenic crop such as RNA-flavored tomatoes by using antisense RNA to control the expression of the enzyme polygalacturonase (PG) to improve its health and self-life, Vitamin-rich vegetables helps to fight heart disease and genetically modified "golden rice" contains vitamin A and iron to prevent malnutrition. (Beyer 2010). In this review efforts are made to consolidate GM crops in global and current agriculture system, their future contribution towards sustainable agriculture, along with the potential risks associated with the environment and human health.

Transgenic crop development method

Genetically modified plants are the result of genetic change in the laboratory by inserting one or more genes to the genome of the plant cell. Nucleus of the plant cell is the goal of transgenic DNA. Development of transgenic crop is necessary to improve agriculture, environment, ecology and also their socio-political impacts. For transgenic crop development DNA is isolated from a desirable donor organism then inserted into a vector genome (Table 1). There are several methods for development of modified crop. Most crops are developed through biological gene gun technique (Biolistic technique) or through transformation methods of *Agrobacterium tumefaciens*.

Gene gun method (Biolistic method)

The most common form of genetic transfer is a genetic modification method, also known as microprojectile bombardment or a biological projectile process. It is used for varieties such as rice and corn. This technique combines DNA with small particles of tungsten or gold, and then injects them into tissue of plant or individual plant cells using a high-pressure gun. Accelerated particles penetrate cell membranes and cell wall of the plant cell. DNA is separated from the binding metal and attached to the plant genome in the nucleus of the plant cell. This method has been used successfully in many plants, especially monocots such as wheat and corn modified with *Agrobacterium tumefaciens*, but with little success (Sonia Plaza-Wüthrich 2012). The only downside of this technique is it may cause injury to cell tissues.

Agrobacterium tumefaciens method

Agrobacterium tumefaciens bacteria has the potential to damage plant cells and cause crown gall disease. The DNA fragment that damages the cell of plant is integrated with chromosome of plants by Tumor induction plasmid or Ti plasmid. The plant cell machinery-controlled Ti plasmid and use to make several copies of its bacterial DNA. Tumor induction plasmid is a large circular DNA and it is independent cell in bacterial chromosome replication. The importance of this plasmid is that it contains DNA transfer (t-DNA) that researchers can implant in a gene that can be transferred in some way to plant cells. This method is called "flower dip". Flower dipping involves immersing flowering plants in an *Agrobacterium* solution which bear the desirable gene, followed by genetically modified seed, collect directly from plants (Jhansi and Usha 2013). This technique is very effective because it is a natural gene transfer method, so it is considered to be a more acceptable technology. More importantly, "*Agrobacterium*" can transfer large fragments of DNA very effectively. This technique is particularly suitable for Dicots such as tobacco, tomato and potatoes plant. According to the study, Arabidopsis and tobacco are the most used transgenic plants, due to easy reproduction, mature transformation technique and well-researched genome (Koornneef and Meinke 2010). *Agrobacterium tumefaciens*

Table 1. Development of transgenic variety in different crops for commercial release.

Crops	Traits	Varieties	Releasing organization/ country
Cotton	Bt- (Cotton, Bollworm, tobacco budworm and Pink bollwarm)	Bollgard	Monsanto
Maize	Bt gene (Corn borer)	Maximizer	Northrup king (Sandoz)
		Yieldgard	Monsanto
	Glufosinate	Libertylink	AgrEvo
Canola	Glufosinate	Inovator	AgrEvo
Soybean	Glyphosate	Roundup Ready	Monsanto
Tomato	Vine ripened shelflife (Antisense RNA Technology)	Flavrsavr	Calgene

method is widely accepted (Gelvin 2003).

RNA interference

This technique is a type of double-stranded RNA (dsRNA) that causes conservative genetic inhibition in a variety of organisms, including plants and animals. Due to its high quality of particularity and performance, it has been extensively accepted as an effective genetic testing tool. RNA intervention is usually performed by genetic modification of a plant by dsRNA, Interference RNA produces hairpin RNA (hpRNA) (Shukla *et al.* 2016). In the vector producing hpRNA, targeted genes are assembled at repeated intervals and unrelated sequences are provided by powerful proponent such as the 35S Cauliflower mosaic virus (CaMV) booster of dicotyledonous and monocotyledonous ubiquitin-1 and also promote high RNA transcription (Hsu *et al.* 2016). When introns are used as spaces, it is very important for the stability of the replicated *E. coli* and efficiency is very high, almost 100% transgenic plants show genetic mutation. However, the way in which introns are made to increase damping efficiency remains unclear. Transgenic technology has advantages over traditional options not only because it increases the range of genes and types of mutations that can be used, but also because they have the ability to control space and time expression. The element of interest directly introduces dsRNA or plasmid hairpin RNA, which leads to rapid particle explosion. It has been shown to create RNAi in plants. This method can be used to analyze the functions of genes, among which transgenic mechanisms that require stable modification are very complex. More recently, the report is one of the most complex RNA disruption systems in plants. Disruption of a genetic component with the help of the use of disruptive RNA is an entrenched mechanism for insect pest genes, mainly based entirely on transport with the help of injecting insect cells or tissues. Recognizing that RNAi may have the potential to reduce genetic expression, measured with the help of mRNA levels, while injectable insects has led to recent issues where mutant plants produce two RNAs (dsRNAs) that can be proven to show insect resistance. Transgenic maize-producing dsRNA-targeted V-kind ATPase-resistant corn rootworm ensures mRNA suppression within the insect and a reduction in feed damage compared to controls (Baum *et al.* 2007). Similarly, transgenic tobacco and Arabidopsis producing an anti-inflammatory enzyme produced by the dsRNA (Cytochrome P450 gene CYP6AE14) depleted gossypol (protective metabolite) in the cotton bollworm caused the insect to become infected with gossyp food (Mao and Zeng 2007). This approach has a good promise for future growth. Similarly, it proves a powerful way to control nematodes (Gillet *et al.* 2017).

How RNAi works

The entry of long dsRNA, such as introduction of transgenes, rough hereditary components, or viral invaders, triggers the cell RNAi pathway. This promotes the registration of Dicer protein. Dicer binds dsRNA into parts of the 2025 base pair, called a small disruptive RNA (siRNA). Then, RNA-induced silence complex (RISC) sees two strands of siRNA as antibody or antisense. The sense strand (which has a system exactly the same as the quality of the policy) has been reduced and the antisense thread is incorporated into the RISC. These are used as rules to direct messenger RNA (mRNA) in a specific collection process. The messenger RNA (mRNA) encoding amino acids is broken down by the silencing complex produced by RNA. Activated RISC continues to contribute to the degradation of mRNA and suppress protein formation.

Need for transgenic crop

The population of the world is overexpanding ; an expected estimate predicts that the world population will reach 10 billion by 2050 and the capacity to supply adequate food is flattering more and more difficult. Malnutrition can be a current and ingrained global economic provocation that reflects the simultaneous impact of indigence, food insecurity, malnourishment, coupled with over-reliance on agricultural reliability. Significant grain malnutrition means malnutrition in developing countries. Most people are malnourished and thus are exposed to a lack of nutrients. Food security is one of the pillar of wellbeing and prosperity in the public eye since people depend on the food not exclusively to get energy toward addition for fundamental supplements that keep up with the insusceptible framework and keep the body in a decent condition of fix. Satisfactory nourishment along these lines relates to slowdown the transience or mortality and dismalness from irresistible and non-irresistible sicknesses especially significant in kids and expectant ladies as the absence of fundamental supplements induce mental and physical harm during development (Black *et al.* 2017). Other benefits of transgenic technology in agriculture include increased crop yields, reduced food or drug production costs, reduced pesticide requirements, improved nutrient and food safety and quality, resistance the pests and diseases, improved food security and brought therapeutic benefits to the world's growing population. There is also progress in building plants that grow faster and can withstand salt, drought, frost and other biotic andabiotic stresses that plants can grow under conditions that would not be able to thrive. The current hunger and malnutrition of the people in Africa and Asia, as well as the larger number of populations who depends on farming for their livelihood, make the decision in favor to adopt transgenic plants. Biofortification, i.e., improvement of nutritional value in plants, is another area where the transgenic technique plays an important role. Advances in traditional production methods to address vitamin A deficiency, which can lead to serious problems - for example, increasing the risk of infant mortality due to diseases such as measles has led to an increase in the exploitation of previously uncultivated agricultural land; as a result, deserts, wetlands, forests and other clean areas intervened, and intervened (Carazo *et al.* 2021). Reducing the loss of biotic stress caused by agricultural pests will somehow increase yields in the current farming environment.

There is no one-size-fits-all solution to this problem, but recent advances in genetic engineering can help increase agricultural productivity and sustain hunger, especially in African countries where there is a great need. These developments can quickly add new features and adapt existing crops to meet new demands and significantly reduce the costs and time taken to improve local varieties of crop (Lu BR 2013). This technique also came up with a way to incorporate various features into plants is quickly than traditional breeding. The genetically modified varieties of corn and cotton that produce Bt pesticides, *Bacillus thuringiensis* (Bt) have become a major agricultural crop worldwide. Especially in developing countries, new species will be key to feeding growing populations to cope with climate change - simultaneously using water and fertilizer, better soil and crop management, and better conservation and transport infrastructure to overcome this we need changing crops that take a lot of change in crop varieties - increased yields resistance to diseases and insect- pests, the value of nutrients or tolerance to drought or floods (Resilient crop) (Varshney *et al.* 2011). To overcome the major obstacles in agriculture, we must turn to a model that combines the best features of transgenic technology with those of organic and traditional agriculture.

Transgenic crop strategies to enhance the nutrients

People can produce almost every organic compound required for typical physiological action however a little number of explicit atoms known as fundamental supplements are needed in the eating routine. A portion of these fundamental supplements are protein, unsaturated fats (Perez-Massot *et al*. 2013), the remain are artificially assorted yet are gathered as nutrients. All transgenic crop systems enhance natural nutrients by adjusting metabolism of crops.

Vitamin A

Reduced gene A (retinal) is required for the production of rhodopsin, which is essential for the detection and assisting of epithelial cells and is unaffected. Vitamin A deficiency leads to several diseases such as night blindness, smooth growth, cell proliferation, intestinal infections. The acidic structure (retinoic corrosive) is made up of morphogen. Humans can bring retina and retinoic corrosive at any time when a source of retinol or one of its esters is supplied, containing a large amount of meat and dairy products. However, the retinal can also be directly linked to b-carotene (otherwise called vitamin A supplements) which is composed mainly of plants and photosynthetic microorganisms but moreover a non-photosynthesizing form of life (Rodriguez-Concepcion *et al.* 2018). Vitamin A deficiency is one of the most common problems in developing countries like India, affecting more than four million children each year, up to 500,000 of whom become partially or completely blind (Tanumihardjo *et al.* 2016). Vitamin A deficiency causes xerophthalmia, a range of eye conditions from night blindness to more severe clinical outcomes such as keratomalacia and corneal scars and permanent blindness. β carotene converted into vitamin A by Human body and the beta-carotene produced by plants (Mostly present in bright red, yellow, orange and some green vegetables) enhanced by increasing carotenoid flow, for example, by increasing the availability of carotenoid precursors, by enzymes expressing in the early stages of the pathway between GGPP and lycopene, by increasing metabolism by promoting b-branch -LYCB flexibility by calling LYCE, or by increasing the ability to cut cells carotenoids to remove response limits (Bai *et al.* 2011, Zhu *et al.* 2009). By the use of genetic engineering synthesized vitamin A have been efficiently distributed among deficient population. Golden rice, which contains β-carotene DXP (1-deoxy-D-xylulose-5-phosphate synthase) Synthase overdose in tomatoes is an example of the first strategy, to produce a precursor carotenoid that increases the flow all the way and improves the overall carotenoid content. The cassava roots that produce the CrtB virus accumulate up to 21 lg / g of carotenoids, a 34-fold increase in wild species (Welsach *et al.* 2010). In cauliflower, the gene increases the final dose of carotenoids to promote the formation of chromoplasts, the production of flexible orange fleshy potatoes containing 10 times the normal amount of β caroten (Lopez *et al.* 2008).

Vitamin C

Ascorbic acid acts as a cofactor for many enzymes, such as carnitine, collagen, cholesterol, hormones, certain amino acids and is powerful antioxidant. Vitamin C deficiency causes ulcers, a disorder characterized by deterioration of connective tissue (Bartholomew 2002). There are many biosynthetic methods that produce ascorbate in plants, and when oxidized ascorbate can be used in many ways with glutathione as a reducing agent. The growing amount of ascorbate in plants can be improved not only by increasing biosynthesis but also by the extent to which molecules are reused. The first method, a method of overdose of L-gulono c-lactone oxidase in lettuce led to the accumulation of ascorbate, a sevenfold improvement (Jain and Nessler 2000). Multivitamin corn that produces a type of rice gene from six ascorbate recycling pathways times at normal levels of ascorbate (Naqvi *et al.* 2009). Transgenic is approaching the development of mineral nutrients is therefore varied, focused plan like to increase the availability of minerals in the rhizosphere, binding to plants, moving them to the end organs, increasing retention the power of the plant, and increase its availability.

Zinc (Zn)

Micronutrient Zn is needed as a cofactor for various enzymes and also acts as a link between the domain that binds DNA to RNA conversion factor. Zinc deficiency affects more than two billion people worldwide and is still developing and appears to be the most common symptoms including hair loss, skin ulcers, fluid imbalance (diarrhea) and eventually muscle damage (Hambidge and Krebs 2007). In recent years, zinc deficiency (Zn) has received increasing attention and appears to be a very dangerous micronutrient deficiency. Indian soil suffers from zinc deficiency a major cause of high bicarbonate concentration. Grains are poor sources of zinc, but these minerals are more soluble than iron and are easier to extract from the soil, Transgenic techniques used to increase zinc content in plants are concentrated in transport and collection (Palmgren *et al.* 2008).

Calcium (Ca)

Soluble calcium is an electrolyte but most of the calcium in the human body is present in minerals as part of the teeth and bone. The replenishment of serum calcium by bone resorption is slow, so temporary calcium deficiency can lead to electrolyte imbalance and later can lead to bone formation. The risk is high in children as the rapid bone growth that occurs in childhood is the highest exposure to calcium. Calcium-rich dairy products are often far removed from most developing countries in children and malnourished adults (Dayod *et al.* 2010). Leafy vegetables and lettuce-like vegetables are good sources of calcium although in some vegetables the high content of phytate and oxalate makes calcium absorption difficult (Jeong and Guerinot 2008). Transgenesis techniques are used to increase the calcium content in plants including exposure to calcium carriers such as AtCAX1, which is three times the amount of calcium in carrots and potatoes (Connolly 2008).

Iron (Fe)

Iron deficiency is the most common form of malnutrition in the world, with more than two billion people at risk. The main clinical manifestation is anemia, which accounts for more than half of all anemia cases worldwide due to iron deficiency (Benoist *et al*. 2008). Biofortification provides a sustainable approach to emerging farmers and many different approaches have been investigated (Wirth *et al*. 2009). One of the biggest challenges with iron is that its movement in the rhizosphere depends on the condition of the soil, because only ferrous (Fe^{2}+) is soluble and is found in plants and Ferric form (Fe^{3} +) does not dissolve in soil particles (Gomez-Galera *et al*. 2012). Plants have two methods, one of which is to reduce soil degradation to convert iron into soluble metal, and the other to remove chelating agents called phytosiderophores (PS) can be replaced by roots such as PS-Fe^{3}+ structures. Iron levels in plants can be improved by increasing the activity of both phytosiderophores and reducing, for example, the level of excess enzymes nicotianamine synthase (NAS) and/or nicotianamine aminotransferase (NAAT) involved in synthosesophore synthesis (Zheng *et al.* 2010, Johnson *et al.* 2011). Mutant rice crops showing NAS genes Osnas1, Osnas2 or Osnas3 accumulated up to 19 µg / g of iron in endosperm (Johnson *et al.* 2011).

Advantages of transgenic plants

GM technology has been used to produce a variety of crop plants to date. As the global population continues to expand, food remains a scare resource. Genetically engineered foods offer significant benefits by improving production yield, lowering transportation costs and enhancing the nutritional content. Developments, resulting in commercially produced varieties in countries such as USA and Canada, have canter on conferring resistance to insect, pests or viruses and producing tolerance to specific herbicides. While these traits had benefits for the farmers, it has been difficult for the consumers to see any benefit other than these. In limited cases, a decreased price owing to reduced cost and increased ease of production (Rani and Usha 2013). Several GM crops for malnutrition are expected to be revealed for cultivation in the coming five to ten years (Davies Kevin 2007).

Herbicide resistant plants

Plants that can endure herbicides are called Herbicide Resistant Plants. Glyphosate is a functioning element of numerous expansive range herbicides. Glyphosate safe transgenic tomato, potato, tobacco, cotton and so forth are created by moving aro. A quality into a glyphosate EPSP synthetase from *Salmonella typhimurium* and *E. coli* Sulphonyl urea safe tobacco plant are delivered by changing the freak ALS (acetolactate synthetase) quality from Arabidopsis. QB protein of photograph framework II from freak *Amaranthus crossovers* is moved into tobacco and different harvests to create atrazine safe transgenic plants (Jhansi and Usha 2013).

Insect resistant plants

Bacillus thuringiensis is a bacterium that is pathogenic for various creepy crawly bothers. Its deadly impact is interceded by a protein poison it produces. Through recombinant DNA strategies, the poison quality can be brought straightforwardly into the genome of the

Table 2. Currently reported varieties and traits including experimental field release or trails.

Crop name	Commercial variety/ trait	Country	Company name	Special property	References
Potato	Alpha, Nortena Rosita	Mexixo, Germany	Byer	Resistance to colorado potato beetle and potato leafroll virus	Jouzani *et al.* (2008)
Papaya	Sun Up, UH rainbow	USA, New Zealand	NA	Viral coat protein gene resistance to ringspot virus	Jouzani *et al.* 2008

plant, where it is communicated and gives assurance against creepy crawly bugs of the plant.

Virus resistant plant

Tobacco mosaic virus resistant tobacco and tomato plants are produced by introducing viral coat proteins. Other viral resistant transgenic plants are (a) Potato virus resistant potato plants, (b) Rice strip virus resistant rice, (c) Yellow mosaic virus resistant black gram and green gram.

Pest resistant plants

If transgenic plants gain resistance to a certain pest, there is definitely an advantage to farmers. Since 1996, papaya resistant to the papaya ring spot virus has been commercialized and farmed in Hawaii (Dong and Ronald 2019). If pesticide consumption is reduced, there may be an environmental advantage as well. Transgenic crops with insect resistance genes from *Bacillus thuringiensis* have reduced the quantity of insecticide used on cotton in the United States dramatically. Pest populations and disease-causing organisms, on the other hand, adapt quickly and develop resistant to insecticides (Table 2).

Use of marginalized land

A vast landmass across the globe, both coastal as well as terrestrial has been marginalized because of excessive salinity and alkalinity. A salt tolerance gene from Mangroves (*Avicennia marina*) has been identified, cloned and transferred to other plants. The transgenic plants were found to be tolerant to higher concentrations of salt. The gut D gene from *Escherichia coli* has been used to generate salt tolerant transgenic maize plants (Farooq *et al*. 2015). Such genes are a potential source for developing cropping systems for marginalized lands. Researchers, at the University of California Davis campus have created transgenic tomatoes that grew well in saline soils. The transgene was a highly-expressed sodium/proton antiport pump which sequestered excess sodium in the vacuole of leaf cells. There was no sodium buildup in the fruit.

Reduced environmental wastage

Water availability and efficient usage have become global issues. Soils subjected to extensive tillage (plowing) for controlling weeds and preparing seed beds are prone to erosion, and there is a serious loss of water content. Low tillage systems have been used for many years in traditional communities. There is a need to develop crops that thrive under such conditions, including the introduction of resistance to root diseases currently controlled by tillage and to herbicides which can be used as a substitute for tillage (Bhardwaj 2013).

Therapeutic proteins from transgenic

Plants proteins of therapeutic importance, like those used in the treatment, diagnosis of human diseases can be produced in plants, using recombinant DNA technology. Scaling-up of these transgenic plants to fields, results in industrial production of proteins. The area of research combining molecular biotechnology and agriculture is called molecular farming or pharming. The proteins produced in transgenic plants for therapeutic use are of three types that is antibodies, proteins and vaccines. Antibodies directed against dental caries, rheumatoid arthritis, cholera, *E. coli* diarrhea, malaria, certain cancers, HIV, rhinovirus, in-

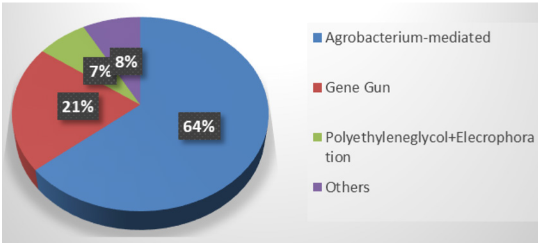

Fig. 1. Gene transfer method.

fluenza, hepatitis B virus and herpes simplex virus are known to be produced in transgenic plants. Vaccines against infectious diseases of the gastro intestinal tract have been produced in plants like potato and bananas (Kushnir *et al.* 2012). Another appropriate target would be cereal grains. An anti-cancer antibody has recently expressed in rice and wheat seed that recognizes cells of lung, breast and colon cancer and hence could be useful in both diagnosis and therapy in the future (Eva and Esperenza 2000). The four major transgenic crops : Soybean, Maize, Cotton, Canola. Soybean maintain its high adaptation rate of 48% of the global transgenic crops (Fig. 1).

Constrains

Transgenic plants with nutritional value have extraordinary ability to cope with poverty, malnutrition and disease especially in developing countries, but there are several issues that prevent the acquisition, cultivation and use of them.

Transport desirable genes together

Plant development with high key levels nutrients need to be transported simultaneously of many desirable genes in the local varieties, which may be uncooperative to transgenic methods. These needs become more complicated when there are several healthy food ingredients demand to be processed simultaneously (Zhu *et al.* 2008, Naqvi *et al.* 2009).

Limits other facilities

The first generation of genetically modified crops has provided significant economic benefits to both advanced and developing farmers (Qaim 2009) and second-generation plants are expected to provide the same social and economic benefits even to consumers and producer (Qaim and Kouser 2013). However, development costs (especially compliance) can be as high as $ 15 million (Kalaitzandonakes *et al.* 2006), which limits access to the facilities of public institutions and small and medium enterprises without access to agricultural resources.

Heavy investment

There are only a few large companies with economic potential to complete the regulatory process and R and D investment will not be repatriated to aid projects (Lemaux 2008). This reduces the motivation for investing in genetically engineered products designed to develop countries (Qaim 2009).

Food safety issue

Food safety are at popular intersections and challenges for many sectors such as biotechnology, agronomy, food technology with the strong focus on safety and quality issue (Chassy 2010). Concern about transgenic plants have been suggested to cause allergic reactions in some people, or in uncertainty, even if the mutant plants are the cause of this reaction (Jhansi and Usha 2013). In addition, antibiotic-resistant genes, which are implanted in these plants, have been shown to form antibacterial resistance, which has led to an increase the potential of insects, which cannot be killed by antibiotics. However, protection of patent allows biotechnology companies to restrict the seed use and also force the farmers to pay high price. In genetically modified crops cross pollination leads to super weed. People do not feel comfortable to insert DNA from another source, such as a bacteria, virus. Concerns about genetically modified plants are harmful to the environment. Another example involves pollen from maize, which has the potential to kill monarch butterflies. It has been shown to be a mixture of corn that shows its toxicity, i.e., at the same time dispersed more than 60 meters by air. In this list, corn pollen is applied to other plants near maize areas, where it is possible to incorporate unknown organisms including the butterfly that led to their death (Jhasi and Usha 2013). According to research it is estimated that the monarch butterfly exposed to Bt corn pollen was fo found to eat less, grow slower and show higher mortality rates.

Future prospect of transgenic plants

Population of the globe will reach 10.5 billion by 2050 and the population is growing in developing countries. Global food production will need a 70% increase, including 3 billion tons of grain, meaning that rice and maize production should double as agricultural land dwindles due to population density in urban areas, land degradation and declining water supply (FAO 2009). Future food security therefore depends on our ability to improve the quality and quantity of food and reduce the global health burden of malnutrition. It will require a variety of partnerships between stakeholders such as health care providers, farmers, nutritionists, vegetable growers, food and agriculture industries, the biotechnology industry, governments and the private sector to reduce the impact of malnutrition on people (Martin *et al.* 2011). We also need to raise awareness of the environmental and plant health benefits, which are widely discussed in the media, such as reducing pesticides and agricultural fuel residues, lowering mycotoxin levels, and reducing exposure to agricultural toxic chemicals (Raybould and Quemada 2010). For example, growing Bt cotton reduces pesticide use by 50% in India, prevents up to nine million cases of toxins and saves $ 51 million (Kouser and Qiam 2011). Bt corn (*Bacillus thuringiensis*) also has low levels of mycotoxins (eg. fumonisin), which save $ 23 million per year from plant losses (*Bacillus thuringiensis*). Elements of a healthy diet therefore need to be combined with the inclusion factors for higher benefits. An additional important subsequent development will be the supplying of incentive for the development of nutritious orphan plants such as sorghum, cassava is planted to a lesser extent in geographical niche place. These plants are not taught the details and often produce less yields and more nutritious food or products than basic plants (Tadele 2009). With enough resources considered they can be developed into one of the foundations of global niche sites. Fluorescent protein (GFP) from jellyfish *Aequorea victoria* has been shown to be effective tool for genetic engineering studies. A great achievement of the GFP as an empowering technology in transgenic plants depends on the success of GFP detection on plants. In the laboratory many researchers use epi-fluorescence microscopes fitted with mercury lamps with blue filters (Mann *et al.* 2012). The transgenic tools have been made easier deploy biologists to fight biotic and abiotic stresses. Transgenic plants designed for their increased tolerance to herbicides and pesticides. Some others have designed to provide biofuel and nutrient rich foods. Healthy fruits and vegetables with low level sugar calorie and vitamin rich are made. Golden rice is transgenic plant. It is rich source of vitamin A (β-carotene) as well iron. Few genetic transgenic plants that are resistant to antibiotics can be picked up by the germs found in the body, thus multiplying their resistance to antimicrobials. There is no doubt that there is a steady increase in the use of flexible plants for human consumption or other important uses. All countries need a well-defined framework for the laws and regulations of the use of plants, although many developed and developing countries have developed laws which includes food processing, pharmaceuticals (including dietary guidelines) and specialized chemicals. Transgenic rubber has been manufactured and will be used for a variety of purposes. Mutable plants therefore have a bright future and hope (Jhansi and Usha 2013).

ACKNOWLEDGMENT

Authors are thankful to University Institute of Agricultural Sciences (UIAS), Chandigarh University for their support and Guidance.

REFERENCES

Bai C, Twyman RM, Farre G, Sanahuja G, Christou P, Capell pell T, Zhu C (2011) A golden era-pro-vitamin enhancement in diverse crops. *In vitro* Cellular *Develop Biol-Pl* 47(2) : 205—221.

Bartholomew M (2002) James lind's treatise of the scurvy. 78 (925) : 695—696.

Baum AJ, Bogaert T, Clinton W, Heck GR, Feldmann P, Ilagan O, Johnson S, Plaetinck G, Munyikwa T, Pleau M, Roberts J (2007) Control of coleopteran insect pests through RNA interference. *Nat Biotechnol* 25 (11) : 1322—1326.

Beyer P (2010) Golden rice and Golden crops for human nutrition. *New Biotech* 27 (5) : 478—481.

Bhardwaj A (2013) Genetically modified crops and sustainability of farm livelihoods : A comparative analysis of India, China and Brazil. *Asian Biotechnol Develop Rev* 15 (2) : 31—59.

Black MM, Walker SP, Fernald LC, Andersen CT, DiGi rolamo AM, Lu C, McCoy DC, Fink G, Shawar YR, Shiffman J, Devercelli AE (2017) Early childhood development coming of age : Science through the life course. *The Lancet* 389 (10064) : 77—90.

Cao Y, Li D (2013) Impact of increased demand for animal protein products in Asian countries : Implications on global food security. *Animal Frontier* 3 : 48—55.

Carazo A, Macakova, K, Matousova K, Kremova LK, Protti M, Mladenka P (2021) Vitamin A update : Forms, sources, kinetics, detection, function, deficiency, therapeutic use and toxicity. *Nutrients* 13 (5) : 1703.

Chassy BC (2010) Food safety risks and consumer health. *New Biotech* 27 : 535—543.

Connolly EL (2008) Raising the bar for biofortification : Enhanced levels of bioavailable calcium in carrots. *Trends Biotech* 26 (8) : 401—403.

Davies Kevin M (2007) Genetic modification of plant metabolism for human health benefits. *Elsevier,* pp 122.

Dayod M, Tyerman SD, Leigh RA, Gilliham M (2010) Calcium storage in plants and the implications for calcium biofortification. *Protoplasma* 247 (3) : 215—231.

De Benoist B, Cogswell M, Egli I, McLean E (2008) World wide prevalence of anemia 1993—2005, WHO global data base of anaemia.

Dong OX, Ronald PC (2019) Genetic engineering for disease resistance in plants : Recent progress and future perspectives. *Pl Physiol* 180 (1) : 26—38.

Eva SCV, Esperanza T (2000) Cereal crops as viable production and storage systems for pharmaceutical scFv antibodies. *Pl Mol Biol* 42 : 583—590.

FAO (2009) A third more mouths to feed : Food production will have to increase by 70%-FAO convenes high-level expert forum. Rome.

Farooq M, Hussain M, Wakeel A, Siddique KH (2015) Salt stress in maize : Effects, resistance mechanisms, and management. A review. *Agron Sustain Develop* 35 (2) : 461—481.

Gelvin SB (2003) Agrobacterium-mediated plant transformation : The biology behind the "gene-jockeying" tool. *Microbiol Mol Biol Rev* 67(1) : 16—37.

Gillet FX, Bournaud C, Antonin JD, Grossi-de-Sa MF (2017) Plant-parasitic nematodes : Towards understanding molecular players in stress responses. *Ann Bot* 119 (5) : 775—789.

Gomez-Galera S, Twyman RM, Sparrow PAC, Van Droogen broeck B, Custers R, Capell T, Christou P (2012) Field trials and tribulations-making sense of the regulations for experimental field trials of transgenic crops in Europe. *Pl Biotech J* 10 : 511—523.

Hambidge KM, Krebs NF (2007) Zinc deficiency : A special challenge. *The J Nutrition* 137 (4) : 1101—1105.

Hsu PY, Calviello L, Wu HYL, Li FW, Rothfels CJ, Ohler U, Benfey, PN (2016) Super-resolution ribosome profiling reveals unannotated translation events in arabidopsis. *Pro Nat Acad Sci* 113 (45) : 7126—7135.

Jain AK, Nessler CL (2000) Metabolic engineering of an alternative pathway for ascorbic acid biosynthesis in plants. *Mol Breeding* 6 : 73—78.

Jeong J, Guerinot ML (2008) Biofortified and bioavailable : The gold standard for plant-based diets. *Proc Nat Acad Sci* 105 (6) : 1777—1778.

Jhansi R, Usha R (2013) Transgenic plants : Types, benefits, public concerns and future. *J Pharm Res* 879—883.

Johnson AAT, Kyriacou B, Callahan DL, Carruthers L, Stangoulis J, Lombi E, Tester M (2011) Constitutive overex pression of the OsNAS gene family reveals single-gene strategies for effective iron-and zinc-biofortification of rice endosperm. *PLOSone* 6 : 01—11.

Kalaitzandonakes N, Alston J, Bradford K (2006) Compliance Costs for Regulatory Approval of New Biotech Crops, chapter in Just R, Alston J, Zilberman D, Regulating Agri-cultural Biotechnol : Economy and Policy, New York : Springer.

Koornneef M, Meinke D (2010) The development of Arabidopsis as a model plant. *The Pl J* 61 (6) : 909—921.

Kouser S, Qiam M (2011) Impact of Bt cotton on pesticide poisoning in smallholder agriculture : A panel data analysis. Ecol Econo 70 : 2105—2113.

Kushnir N, Streatfield SJ, Yusibov V (2012) Virus-like particles as a highly efficient vaccine platform : Diversity of targets and production systems and advances in clinical development opment. *Vaccine* 31 (1) : 58—83.

Lal M, Jamwal M, Sood Y, Bakshi P, Sharma N, Sharma S, Kumar S (2022) Micropropagation of fruit crops- A review. *Pl Sci Today* 10 (1) : 108—117.

Lemaux PG (2008) Genetically engineered plants and foods : A scientist's analysis of the issues (Part I). *Annual Rev Pl Biol* 59 : 771—812.

Lopez AB, Van Eck J, Conlin BJ, Paolillo DJ, O' Neill J, Li L (2008) Effect of the cauliflower or transgene on carotenoid accumulation and chromoplast formation in transgenic potato tubers. *J Experim Bot* 59 (2) : 213—223.

Lu BR (2013) Successful Agricultural Innovation in Emerging Economies (eds Bennett, DV and Jennings RC) Ch. 9 (Cambridge Univ Press).

Mann DG, LaFayette PR, Abercrombie LL, King ZR, Mazarei M, Halter MC, Poovaiah CR, Baxter H, Shen H, Dixon RA, Parrott WA (2012) Gateway-compatible vectors for high-throughput gene functional analysis in switchgrass (*Panicum virgatum* L.) and other monocot species. *Pl Biotech J* 10 (2) : 226—236.

Mao J, Zeng F (2007) Plant-mediated RNAi of a gap gene-enhanced tobacco tolerance against the *Myzus persicae*. *Transgenic Res* 23 : 145—152.

Martin C, Butelli E, Petroni K, Tonelli C (2011) How can research on plants contribute to promoting human health ? *Pl Cell* 23 : 1685—1699.

Naqvi S, Zhu C, Farre G, Ramessar K, Bassie L, Breitenbach J, Christou P (2009) Transgenic multivitamin corn through biofortification of endosperm with three vitamins representing three distinct metabolic pathways. *Proceed National Acad Sci* 106 (19) : 7762—7767.

Palmgren MG, Clemens S, Williams LE, Kramer U, Borg S, Sch-Schjørring JK, Sanders D (2008) Zinc biofortification of cereals : Problems and solutions. *Trends Pl Sci* 13 (9) : 464—473.

Perez-Massot E, Banakar R, Gomez-Galera S, Zorrilla-Lopez U, Sanahuja G, Arjo G, Miralpeix B, Vamvaka E, Farre G, Rivera SM, Dashevskaya S, Berman J, Sabalza M, Yuan D, Bai C, Bassie L, Twyman RM, Capell T, Christou P, Zhu C (2013) The contribution of transgenic plants to better health through improved nutrition : Opportunities and constraints. *Genes Nutrition* 8 (1) : 29—41.

Qaim M (2009) Economics of GM Crops. *Annual Rev Reso Econ*

1 : 665—693.

Qaim M, Kouser S (2013) Genetically modified crops and food Security. *PLoSOne* 8 (6) : e64879.

Rani SJ, Usha R (2013) Transgenic plants : Types, benefits, public concerns and future. *J Pharmacy Res* 6 (8) : 879—883.

Raybould A, Quemada H (2010) Bt crops and food security in developing countries : Realized benefits, sustainable use and lowering barriers to adoption. *Food Security* 2 : 247—259.

Rodriguez-Concepcion M, Avalos J, Bonet ML, Boronat A, Gomez A, Gomez-Gomez L, Hornero-Mendez D, Limon MC, Me lendez-Martínez AJ, Olmedilla-Alonso B, Palou A, Ribot J (2018) A global perspective on carotenoids: Metabolism, biotechnology and benefits for nutrition and health. *Prog Lipid Res* 70 : 62—93.

Shukla Jayendra Nath, Kalsi Megha, Sethi Amit, Kenneth E Narva, Fishilevich Elane, Singh Satnam, Mogilitracellular Kanakachari and Palli Subba Reddy. "Reduced stability and intracellular transport of dsRNA contribute to poor RNAi response in lepidopteran insects." RNA biology 13, no. 7 (2016) : 656—669.Tenea GN (2009) Exploring the world of RNA interference in plant functional genomics : A research tool for many biology phenomena. *Center Microbial Biotechnol*, pp 4360—4364.

Sonia Plaza-Wüthrich (2012) Millet improvement through regeneration and transformation. *Biotech Mol Biol Rev* 7 (2) : 48—61.

Tadele Z (2009) New approaches to plant breeding of orphan crops in Africa. In: Proceedings of an international conference, 19—21 September 2007, Bern, Switzerland.

Tanumihardjo SA, Russell RM, Stephensen CB, Gannon BM, Craft NE, Haskell MJ, Lietz G, Schulze K, Raiten DJ (2016) Biomarkers of Nutrition for Development (BOND)-Vitamin A review. *The J Nutrition* 146 (9) : 1816—1848.

Tohidfar M, Jouzani GS (2008) Genetic engineering of crop pl-crop plants for enhanced resistance to insects and diseases in Iran. *Transgenic Pl J* 2 (2) : 151—156.

Varshney RK, Bansal KC, Aggarwal PK, Datta SK, Craufurd PQ (2011) Agricultural biotechnology for crop improvement in a variable climate : Hope or hype ? *Trends Pl Sci* 16 (7) : 363—371.

Welsach R, Arango J, Bar C, Salazar B, Al-Babili S, Beltran J, Beyer P (2010) Provitamin accumulation in cassava (*Manihot esculenta*) roots driven by a single nucleotide poly morphism in a phytoene synthase gene. *The Pl Cell* 22 (10) : 3348—3356.

Wirth J, Poletti S, Aeschlimann B, Yakandawala N, Drosse N, Osorio S, Tohge T, Fernie AR, Gunther H, Gruissem W, Sautter C (2009) Rice endosperm iron biofortification by targeted and synergistic action of nicotianamine synthase and ferritin. *Pl Biotech J* 7 (7) : 631—644.

Zhao D, Wang H, Chen S, YuRussel D, Reiter J (2021) Phytomelatonin : An emerging regulator of plant biotic stress resistance. *Trends Pl Sci* 26 (1) : 70—82.

Zheng L, Chengz AiC, Jiang X, Bei X, Zheng Y, Glahn RP, Welch RP, Miller DD, Lei XG, Shou H (2010) Nicotianamine, a novel enhancer of rice iron bioavailability to humans. *PLoSone* 5 : 01—07.

Zhu C, Naqvi S, Breitenbach J, Sandmann G, Christou P, Capell T (2008) Combinatorial genetic transformation generates a library of metabolic phenotypes for the carot enoid pathway in maize. *Proc Nat Acad Sci* 105 (47) : 18232—18237.

Zhu C, Naqvi S, Capell T, Christou P (2009) Metabolic engineering of ketocarotenoid biosynthesis in higher plants. *Arch Biochem Biophysics* 483 (2) : 182—190.