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Transgenic Crops: Recent Trends & Future Prospects

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Introduction:

The increasing human population necessitates doubling the world food production in the upcoming decades. A number of possible biotechnological measures are under consideration but the central to these efforts is the development of transgenic crops to produce more food and the plants that can better adapt to adverse environmental conditions in a changing climate.

According to the ISAAA (International Service for the Acquisition of Agri-Biotech Applications) report, GM crops were cultivated over 185 million ha in 2016.Genetic modification of plants has become the most promising approach to fight poverty by increasing crop yield, to meet nutrient deficiency, to reuse salt-affected lands, to overcome the energy crisis and to produce cost-effective biopharmaceuticals using plants as cellular factories.

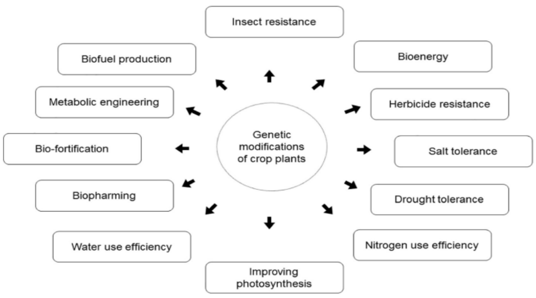

Fig. 1. Common targets of GM modifications in crop plants.

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First three major transgenic crops growing countries are Argentina (24.3 mh), Brazil (42.2 mh) and US (73.1 mh). Monsanto, Dupont and Syngenta are three largest companies in world that are utilizing plant gene technology. In 1994 first GM plant 'FlavrSavr' tomato was released for human consumption which has been modified to contain reduced levels of cell wall softening enzyme polygalacturonase.

Status in India

Currently, India has the world's fourth largest GM crop acreage surpassing China's 3.0 million hectares (mh), while equaling that of Canada's 11.6 mh, according to the International Service for the Acquisition of Agri-Biotech Applications (ISAAA). In 2014, farmers in India planted a total 11.6 mh under transgenics. Field trials for 21 GM food crops, including GM vegetables and cereals have been approved by the government though commercial cultivation of GM food has not been permitted by any State government in India till now.

Bt Cotton: The only genetically modified cash crop under commercial cultivation in India is cotton. Bt cotton was first used in India in 2002.Nearly 96% (nearly ~ 11.57 mh) of the country's cotton area is now covered by Bt hybrids. Bt cotton is based on the US life sciences giant Monsanto's proprietary "Bollgaurd" technology.

Bt Brinjal: In 2009, India's Maharashtra Hybrid Seeds Company (Mahyco) and US based company Monsanto have developed Bt eggplant (*Solanum melongena*) by inserting a crystal

gene (Cry1Ac) from *B. thuringiensis* (Krattiger, 2010; Cotter, 2011). The GEAC in 2007 recommended the commercial release of Bt Brinjal, which was developed by Mahyco (Maharashtra Hybrid Seeds Company) in collaboration with the Dharward University of Agricultural Sciences and Tamil Nadu Agricultural University. But the initiative was blocked in 2010.

GM-mustard: Dhara Mustard Hybrid-11 or DMH-11 is a genetically modified variety of mustard developed by the Delhi University's Centre for Genetic Manipulation of Crop Plants. The researchers at Delhi University have created hybridised mustard DMH-11 using "barnase /barstar" technology for genetic modification. It is Herbicide Tolerant (HT) crop. If approved

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by the Centre, this will be the second GM crop, after Bt Cotton, and the first transgenic food crop to be allowed for cultivation in the country.

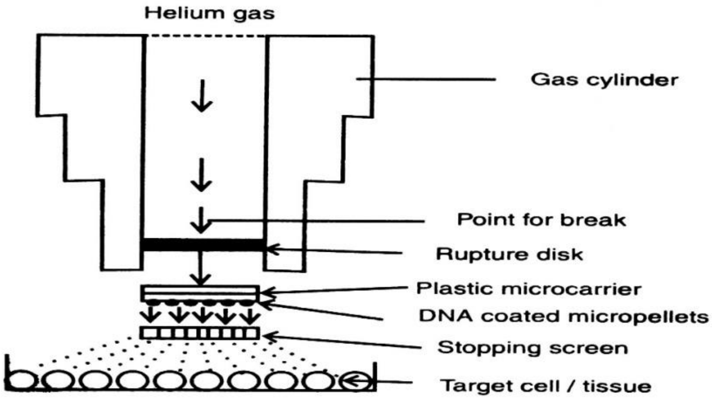
Transgenic plants

Transgenic plants simply mean plants carrying foreign genes. Transgenic plants are the plants whose DNA is modified using genetic engineering techniques. Transgenic plants can be developed by inserting transgenes into any of the three genomes i.e. nuclear, plastidal or mitochondrial. This process provides advantages like improving shelf life, higher yield, improved quality, pest resistance, tolerant to heat, cold and drought resistance, against a variety of biotic and abiotic stresses. Transgenic plants can also be produced in such a way that they express foreign proteins with industrial and pharmaceutical value.

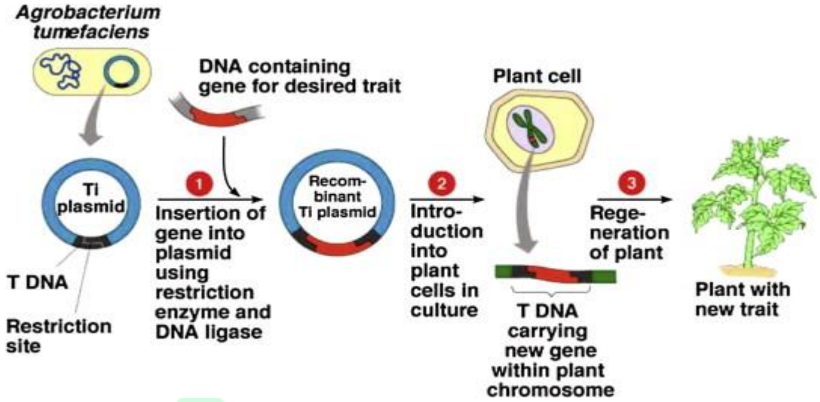
Development of transgenic crops

Genetically engineered plants are generated in a laboratory by altering the genetic-make-up by adding one or more genes in a plant's genome. The nucleus of the plant-cell is the target for the new transgenic DNA. Most genetically modified plants are generated by the **biolistic method** (Particle gun method) or by ***Agrobacterium tumefaciens*** mediated transformation method.

The **"Gene Gun" method**, also known as the "Micro-Projectile Bombardment" or "Biolistic" method is most commonly used in the species, especially monocots, like wheat or maize. In this method, DNA is bound to the tiny particles of Gold or Tungsten, which is subsequently shot into plant tissue or single plant cells, under high pressure using gun. The accelerated particles are penetrating both into the cell wall and membranes. The DNA separates from the coated metal and it integrates into the plant genome inside the nucleus. This technique is clean and safe. The only disadvantage of this process is that serious damage can be happened to the cellular tissue.



The next method, used for the development of genetically engineered plants, is the **"Agrobacterium" method**. It involves the use of soil-dwelling bacteria, known as *Agrobacterium tumefaciens*. It has the ability to infect plant cells with a piece of its DNA. The piece of DNA, that infects a plant, is integrated into a plant chromosome, through a tumor inducing plasmid (Ti plasmid). The Ti plasmid can control the plant's cellular machinery and use it to make many copies of its own bacterial DNA. The Ti plasmid is a large circular DNA particle that replicates independently of the bacterial chromosome. The importance of this plasmid is that, it contains regions of transfer DNA (t DNA), where a researcher can insert a gene, which can be transferred to a plant cell through a process known as the "floral dip". A Floral Dip involves, dipping flowering plants, into a solution of Agrobacterium carrying the gene of interest, followed by the transgenic seeds, being collected directly from the plant. This process is useful, in that, it is a natural method of transfer and therefore thought of as a more acceptable technique. In addition, "Agrobacterium" is capable of transferring large fragments of DNA very efficiently. One of the biggest limitations of Agrobacterium is that, not all-important food crops can be infected by these bacteria. This method works especially well for the dicotyledonous plants like potatoes, tomatoes and tobacco plants. In research, tobacco and Arabidopsis thaliana are the most genetically modified plants, due to well-developed transformation methods, easy propagation and well-studied genomes. They serve as model organisms for other plant species. Transgenic plants have also been used for bioremediation of contaminated soils. Mercury, selenium and organic pollutants, like as polychlorinated biphenyls (PCBs), have been removed from soils by transgenic plants, containing genes for bacterial enzymes.



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. Developments, resulting in commercially produced varieties in countries such as USA and Canada, have centers 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. Several GM crops for malnutrition are expected to be revealed for cultivation in the coming five to ten years.

Herbicide resistant plants

Plants that can tolerate herbicides are called Herbicide Resistant Plants. Glyphosate is an active ingredient of many broad-spectrum herbicides. Glyphosate resistant transgenic tomato, potato, tobacco, cotton etc. are developed by transferring **aro A** gene into a glyphosate EPSP synthetase from *Salmonella typhimurium* and *E. coli* Sulphonylurea resistant tobacco plants are produced by transforming the mutant ALS (acetolactate synthetase) gene from Arabidopsis. QB protein of photo system II from mutant Amaranthus hybrids is transferred into tobacco and other crops to produce atrazine resistant transgenic plants.

Insect resistant plants

Bacillus thuringiensis is a bacterium that is pathogenic for a number of insect pests. Its lethal effect is mediated by a protein toxin it produces. Through recombinant DNA methods, the toxin gene can be introduced directly into the genome of the plant, where it is expressed and provides protection against insect pests of the plant

Virus resistant plants

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TMV 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) RSV resistant rice, (c) YMV resistant black gram and (d) YMV resistant green gram etc.

Pest resistant plants

There is clearly a benefit to farmers, if transgenic plants are developing a resistant into specific pest. For example, Papayaring-spot-virus resistant papaya has been commercialized and grown in Hawaii since 1996.12 there may also be a benefit to the environment, if the use of pesticides is reduced.

Nutritional benefits

Vitamin A deficiency causes half a million children to become partially or totally blind each year. Milled rice is the staple food for a large fraction of the World's human population. Traditional breeding methods have been unsuccessful in producing crops; containing a high concentration of vitamin A. Researchers have introduced three genes into rice: two from daffodils and one from a microorganism. The transgenic rice exhibits an increased production of beta-carotene as a precursor to vitamin A and the seed is yellow in colour. Such yellow, or golden, rice may be a useful tool to treat the problem of vitamin A deficiency in young children living in the tropics

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. Such genes are a potential source for developing cropping systems for marginalized lands (Swaminathan, Personal Communication, 2000).

Reduced environmental impact

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.

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 (i) antibodies, (ii) proteins and (iii) vaccines. Antibodies directed against dental caries, rheumatoid arthritis, cholera, E. coli diarrhoea, malaria, certain cancers, HIV, rhinovirus, influenza, 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. 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.

Disadvantages of transgenic crops

The use of transgenic crops was an issue for many years. Many concerns have been raised and these are falling into two categories.

1. A concern, about what affect genetically modified material, could have on human health. For example, transgenic crops have been suggested to cause allergies in some people, although it is uncertain, whether transgenic crops are the source of this reaction.

2. A concern, about whether transgenic crops cause damage to the natural environment. One example that includes pollen from transgenic corn, which has capacity to kill the Monarch butterfly larvae.

The following are, however, potential issues of concern for plant protein production.

1) Allergic reactions to plant protein glycans and other plant antigens.

2) Plant and product contamination by mycotoxins, pesticides, herbicides and endogenous metabolites.
3) Regulatory uncertainty, particularly for proteins requiring approval for human drug use.

Conclusion

The advancements made with transgenic plants have and will continue to have a great impact on the lives of many. More research is required in this field to determine the true safety of these plants and to decide, whether they are safe for both the environment and for those, who consume these products over the ages. Transgenic plants offer a new approach to producing and administering human antibodies. The use of genetic engineering for the production of biopharmaceuticals like erythropoietin to treat anaemia and insulin to treat diabetes are well known. Future generations of GM plants are intended to be suitable for harsh environments and for the Enhancement of Nutrient content, production of pharmaceutical agents and production of Bioenergy and Biofuels.