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REVIEW ARTICLE

Recent Advances in Transgenic Crop development: Success and Controversies in The Commercial Application

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ABSTRACT
Genetic modification, a subfield of biotechnology, entails changing a living thing's genetic makeup to enable it to perform a certain function. The advantages of Genetically modified crops are quite widespread, and they span from improved food production features to health advantages. In addition to improving food security and lowering health inequities, GM foods also have the potential to generate higher-quality, more nutritious meals. However, due to the presence of certain concerns, it is required to examine the emerging transgenic plants more closely as the technology advances. In this particular review, we will be discussing about the biotechnological tools for producing the GM crops, the challenges and solution of commercial agriculture, ethical concern and risk assessment associated with the GM crops as well as the future prospect of the same.
Keywords: Genetic modification, Gene gun, Mycogen

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INTRODUCTION

The branch of biotechnology known as genetic modification deals with altering the genetic makeup of living things so that they can carry out particular tasks (46). In 1946, when scientists first learned that genetic material could be transferred between various species, breakthroughs took place that would eventually lead to modern genetic manipulation. Following this, Watson and Crick discovered the double helix shape of DNA and developed the fundamental theory in the year 1954. Boyer and Cohen's groundbreaking studies in 1973 involved 'cutting and pasting' DNA between several species employing restriction endonucleases as well as DNA ligase, also known as 'molecular scissors' and 'glue' respectively, and as a result, the first GM organism was successfully created.

The first genetically modified plants in agriculture, tobacco and petunia, had been successfully developed in the year 1983. China was the first nation which commercialised genetically modified tobacco for viral resistance in 1990. The Flavr Savr tomato was the first genetically modified plant ever authorized for human consumption by the Food and Drug Administration in the year 1994. Ever since, in 1995 and 1996, a number of transgenic crops have been given the go-ahead for extensive human cultivation.

The benefits of GM food are quite pervasive, including a range of features of enhanced food production as well as benefits related to health. The of GM foods also assists in enhancing food security and reducing health disparities as well as has the potential to produce food with better nutrient and offer greater quality, as in the case of golden rice (11) (41). Agricultural produce can be genetically altered using food biotechnology to become pest-resistant and weather-resistant, yield better yields, as well as increase quality and nutrition. This results in the reduction of dependency on pesticides, hence creating crops which are safer for consumption; creating crops which are weather tolerant and increasing the food value of the crops.

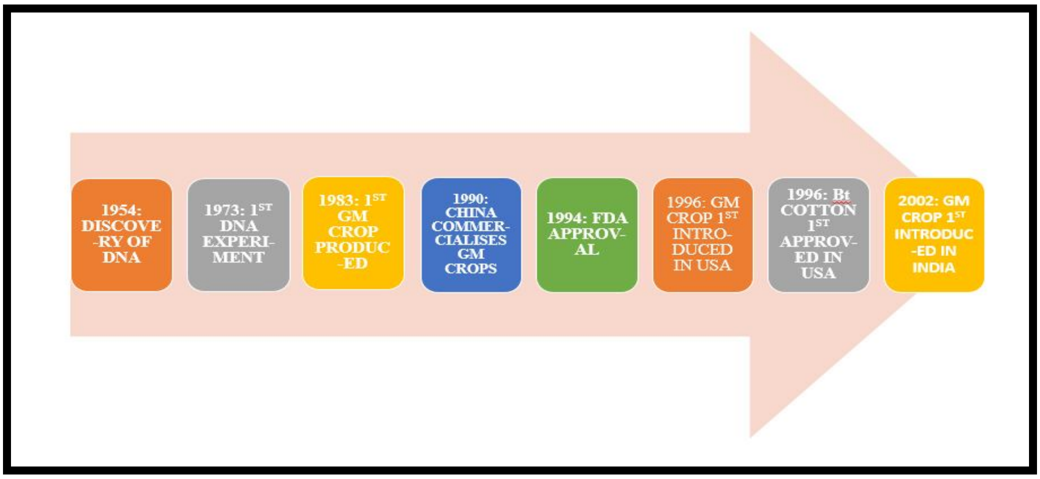

Figure-1: Timeline for the Evolution of Genetically modified crops

In this study, we'll look into the biotechnological methods used to create GM crops, the problems and solutions faced by commercial agriculture, the moral issues and risks related to GM crops, and their potential in the future.

DIFFERENT BIOTECHNOLOGICAL TOOL IN PRACTICE

Agrobacterium-mediated transformation as well as the use of a gene gun to directly transfer the gene are the two most common techniques for introducing foreign genes into plant cells (36.).

Plant genetic engineering has greatly benefited from the ability of agrobacterium which can transfer the genes into plant cells, where they can be incorporated stably into the host chromosome and hence get expressed (22). The infected DNA fragment is incorporated into the plant chromosome by a tumor-inducing plasmid, also known as Ti plasmid. By influencing the plant's biological machinery, the Ti plasmid can use it to duplicate the DNA of its host bacteria. Ti plasmids are enormous circular DNA particles which can replicate without the help of bacterial chromosomes. This plasmid is crucial because it includes transfer DNA regions where a scientist may insert a gene that can be transferred to a plant cell using a called 'floral dip' (29).

In a Floral Dip, flowering plants are submerged in a solution of Agrobacterium, which contains the desired gene before being collected for transgenic seeds right from the plant. Being unable to infect all important food crops is one of Agrobacterium's biggest drawbacks. Dicotyledonous plants like potatoes, tomatoes, as well as tobacco plants respond well to this strategy (9).

A method for physically delivering DNA into the plant cells possessing cell walls is called gene gun bombardment technique. The plant cell wall is bombarded by many metal particles coated with DNA and fired from the gene cannon using compressed He as the propellant. Transduction of DNA is far more effective than other methods since the particles really enter the cytosol as well as cell nucleus, needing much lesser amount of DNA plasmid (30). The common metals which are utilized in the gene gun bombardment technique include gold, tungsten, palladium, rhodium, platinum, and even iridium. After being propelled by helium gas as well as coated with DNA, they can be bombarded to the plant cells (12.).

The gene gun incorporates the DNA into the genome of the host cell using metal beads as carriers. Since the early 1990s, plant biotechnologists have utilised particle bombardment extensively and it has proven to be a highly effective method for transferring genes to plant cells (2). The gene gun method has several drawbacks, including the possibility that occasionally, particles could enter the cell empty, harming cells, and the possibility that occasionally, DNA could enter unintended cells, leading to the emergence of herbicide resistance in case of the weed plants (10).

MAJOR CROPS WITH COMMERCIAL BIOTECHNOLOGY-BASED INPUT TRAITS

Fifteen crop plants, including maize, soybeans, cotton, canola, and others, have been developed with GM traits since the first GM crop was commercialised in the mid-1990s (18;21).

The initial commercially available GM maize traits comprised single gene traits that expressed either the HT or the IR genes separately. In 1996, Bayer introduced Mycogen Seeds, the first variety of maize with resistance against lepidopteran insect pests, and Liberty Link® corn, a kind of corn that is tolerant to the herbicide glufosinate. Three categories of GM maize products can be found for different markets: only HT, lepidopteran IR Plus HT, and lepidopteran + coleopteran IR + HT. The main applications of HT-only maize are as a refuge for IR goods and also in a few specialised markets with little amount of pest pressure. Lepidopteran IR + HT products can target aboveground insects that are pests of maize worldwide, such as the European corn borer, corn earworm, and autumn armyworm. Lepidopteran and coleopteran IR + HT treatments target both aboveground and belowground pests, including the predominantly North American pest maize rootworm.

Since its commercialization in 1996, Monsanto's glyphosate-tolerant Roundup Ready® trait has been the most common soybean trait. The trait was present on more than 50% of US soybean acres by 2000, and by the year 2007, adoption had risen above 90%, where it is now (13). Therefore, IR soybean has not been commercialised in the USA but has primarily been commercialised in South America. This is because major lepidopteran pests that attack soybean, in specific soybean looper as well as velvetbean caterpillar, are indeed a serious issue in South America but are not generally of concern in the USA. Several fresh GM soybean traits have either been released or are anticipated to do so shortly.

For the first time, GM IR cotton had been introduced in the USA in 1996, followed by HT and the stacked IR + HT product, a year later in 1997 (13). For the first time, GM IR cotton had been introduced in the USA in 1996, followed by HT and the stacked IR + HT product, a year later in 1997. Therefore, IR soybean has not been commercialised in the USA but has primarily been commercialised in South America. This is because important lepidopteran pests that attack soybean, specifically soybean looper as well as velvetbean caterpillar, are a major problem in South America and are not really of concern in the USA (21).

In 2015, twenty-four percent of the world's canola acres—21 million acres were planted with GM canola (7). HT plus male sterility are the only GM characteristics found in canola to date. Bayer developed glufosinate-tolerant canola in Canada in the year 1996, and Monsanto unveiled glyphosate-tolerant canola in 1997. To aid in the development of hybrid canola seed, Bayer added a GM male sterility system to their HT canola trait.

Several smaller crops have also been commercialised with GM input characteristics. With varying degrees of success, traits which confer resistance to particular diseases have been marketed in papaya, potato, plum, and squash. These tiny crops contain some disease resistance features that have gained widespread market acceptance and are credited with preserving specific agricultural businesses. Smaller crops that contain herbicide-tolerant characteristics have also encountered difficulties (21)

TABLE-1: Commercial Genetically modified crops

Trait	Description of Trait	Crop	References
Disease resistance	Viral resistance	Plum	[20]
		Papaya	
		Potato	
		Squash	
Tolerance to herbicides	Glyphosate tolerance	Alfalfa	[6]
		Canola	
		Cotton	
		Maize	
		Soybean	
		Sugar beet	
	Glufosinate tolerance	Canola	[44]
		Cotton	
		Maize	
		Rice	
		Soybean	
	2,4 D tolerance	Cotton	[15]
		Maize	
		Soybean	
	Dicamba tolerance	Cotton	[42]

		Soybean	
Pest resistance	Lepidopteran tolerance	Cotton	[16]
		Eggplant	
		Maize	
		Potato	
		Soybean	
	Coleopteran resistance	Maize	[16]
		Potato	
Male sterility	Male sterility	Canola	[34]
		Maize	
Agronomic traits	Drought tolerance	Maize	[25]
	Volumetric wood increase	Eucalyptus	[17]
Output traits	Altered lignin	Alfalfa	[31]
	Maize	Increased lysine	
	Altered starch	Potato	
	Modified oil	Soybean	
		Canola	
	Phytase production	Canola	
	High lycopene	Pineapple	

CHALLENGES AND SOLUTION IN COMMERCIAL AGRICULTURE

Due to their toxicity, allergenicity, and hereditary concerns, GM crops may pose significant health risks. These might result from naturally occurring gene disruption in GMOs, from inserted gene products as well as the potential pleiotropic effects associated with it, or from a combination of both (28). The cultivar Starlink maize, which expresses Cry9c and confers gluphosinate tolerance, is the most documented case of this (4; 46). Owing to its ability for the interaction with the human immune system, Cry9c Starlink was categorised as "possibly allergenic" by the USDA's Scientific Advisory Panel in the middle of the 1990s. Starlink was approved to be used in commercial animal feed as well as industries by the US Environmental Protection Agency in 1998, but it was prohibited for human use (8).

Pest resistance is presently another issue with GM crops as a result of gene overexpression driving pest evolution through natural selection. According to a study carried out by Tabashnik et al., in 2013, 5 out of the 13 key pest species evaluated had field-evolved pest resistance, compared to just 1 in 2005, out of the results of 77 investigations (38). Additionally, because most insects have limited lifespans, such resistance may be evolved through a number of generations in a relatively short time.

Strict regulatory frameworks have been developed in order to prevent the cross-contamination with the split-approved GM crops that are prohibited from being consumed by humans in order to reduce the issues with GM technologies. These include establishing and enforcing buffer zones that can stop crop contamination, improving laboratory test to verify cases of adverse allergic events, and generally involving stakeholder as well as representative groups in the process of policymaking and communication (8).

Additionally, the incorporation of elevated dosage of Bt toxin standards in case of the transgenic crops and monitoring insect reactions, the incorporation of host plant resistance traits in cultivars so as to regulate secondary pests, and the creation of ample non-Bt plant refuges close to the Bt crops can all help to reduce Bt pest resistance [38, 39]. If adopted, these recommended pest management as well as regulation approaches could assist the agricultural business in overcoming the drawbacks of GM crops and considerably boost public confidence in this technology.

GM crops: Merits and Demerits

Genetically modified plants may offer potential advantages, but they also carry known and unknowable hazards, just like any other technology, old or new. The main emphasis is on the scientific foundation for evaluating the advantages and hazards of GM crops on public health and the environment (35).

Some transgenic crops, like cotton, boost yield while lowering agricultural production costs. Bt cotton, which generates an insect control protein from naturally present soil bacterium *Bacillus thuringiensis* subsp. kurstaki, is a fairly well-known GM crop created by Monsanto. The cotton plant produces the Cry1Ac protein, which protects it from major Lepidopteran insect pests like the cotton bollworm as well as pink bollworm (5; 43).

The most obvious environmental advantage mentioned for transgenic crop plants is the decrease in the usage of pesticides for pest management. Pest resistance genes are present in the majority of transgenic crops, including soybean, corn, cotton, and canola, leading to a large reduction in pesticide use (5). There has been a lot of interest in plant-based environmental remediation, also known as phytoremediation, as an effective clean-up solution in recent times. The use of transgenic plants as a method to identify and address environmental pollution has been suggested (23).

A wide range of biopharmaceuticals, such as monoclonal antibodies, enzymes, serum proteins, and novel subunit vaccines, can be produced on a large scale via transgenic plant study, including safe, pure, as well as highly effective therapeutic proteins. With more than 200 medicines undergoing clinical testing for the treatment of serious and chronic diseases, monoclonal antibodies are among the therapies with the fastest rising market share (14).

The ecology as well as toxicology of the GM crops after release and use are subject to risk. Through genetic engineering, allergens can be introduced into recipient plants (24). Food toxicity testing is required when a plant produces excessive amounts of its natural chemicals or if a transgenic product is known to be harmful (19).

The non-target creatures may be harmed by transgenic crops which may express insecticidal transgenes to suppress agricultural pests. Transgenic Bt-plants may have toxic effects on species those are beneficial to agriculture because they are parasites or predators of pests rather than actual pests of the crop (33).

There are worries that the introduction as well as widespread cultivation of genetically modified crops with pest or resistance to disease may put strong selection pressure upon pest and pathogen communities for the adoption of the resistance mechanism (37). The main motivation behind the resistance of numerous powerful environmentalist organisations opposing GM crops is concern about the biodiversity loss. It was proposed that GM crops would endanger diversity of crops or outgrow the region's flora, harming natural species (32).

CHALLENGES OF COMMERCIALIZATION

Despite the fact that GM crops have advantages for the economy, society, and environment worldwide, their acceptance is still problematic in many regions of the world, including Africa and Europe (26; 27). This opposition stems from a variety of intricate and interrelated issues that have existed since the introduction of GM foods but has only as much to do with social and political ideals as it does with health and safety concerns (45). Some of the underlying worries about widespread adoption have itself turned into a driving force for the establishment of GM agricultural rules and policies. This part emphasises the perception of the risks and benefits of GM crops and food, political and regulatory development, protection of global trade, and social issues.

Transgenic crop intellectual property can be protected in a variety of ways, including plant breeding, patenting, and also sui generis mechanisms for protection. Depending on the nation, groups will pursue various legal types of protection when releasing new plant varieties (3). Regarding this matter, developing nations are under intense pressure, primarily from the USA, to embrace intellectual property agreements that go beyond the WTO's minimal standards (40). But other non-governmental organisations assert that the subject of crop patenting jeopardises small farmers' access to seeds. Many private biotech advancements have been controversially influenced by intellectual property rights (1).

FUTURE OF TRANSGENIC CROPS

If both the developing as well as developed worlds have the technology to use GM crops, then transgenic modification, both traditional and contemporary to plant and animal food sources holds potential for the improvement of human nutrition and health. Genetically modified plants may offer potential advantages, but they also carry known and unknowable hazards, just like any other technology, old or new. The main emphasis is on the scientific foundation for evaluating the advantages and hazards of GM crops on human health and the environment (35).

Edible plant vaccines offer a potential illustration of a novel approach that combines advancements in medical research and plant biology to produce pharmaceutical goods at a reasonable price. Transgenic crops are just recently and increasingly being used for the production of pharmaceuticals, human therapeutic proteins, consumable vaccinations, and phytoremediation (26). It is necessary to build and improve coordinated multigene modification in plants to provide more resilient transgenic procedures that can streamline authorization as well as reassure the public regarding the stability and safety of GM products (35).

CONCLUSION

New features are being bred into plants through biotechnology, which has the potential to increase agricultural output, benefit the environment, and improve human health and nutrition. In the latter half of the twentieth century, improvements in scientific knowledge and laboratory methods resulted in the

creation of effective methods for the transformation, selection, as well as detection of the transgenes, as well as for determining their future through the application of biotechnology.
On the usefulness as well as safety of the Genetically Modified crops intended to increase agricultural productivity, the public seems to be split. If GM crops materially differ from non-GM counterparts in terms of safety, composition, or even nutritional value, or if they include a recognized allergy, they must be labelled. It will be required to examine the emerging transgenic plants further closely as the technology advances. Conducting rigorous testing of transgenic plant in order to make sure they don't endanger human health would indeed as a part of better regulation.

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