Impact of Genetic Engineering on Agriculture Applications

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Abstract

The primary goal of modern agriculture is to increase the amount and quality of crop production. Bacteria and other small organisms, plants, and animals can all be genetically modified. Genetic engineering helps the scientists to even transfer the targeted genes of one plant to another. This is also referred to as Genetically Modified Organisms (GMOs). Plants can be genetically modified to acquire particular traits. Even though this process differs from traditional breeding, it boosts the effectiveness in crop yield. The increased crop yields, lowered costs for food or drug production, reduced pesticide requirement, improved nutrient composition as well as food quality, increased pest and disease resistance, increased food security, and medical benefits are considered as the major objectives of genetic engineering in agriculture domain. This research study discusses about the genetically modified crops, their processes, advantages and the novel state-of-the-art cropping trends.

Keywords: crop production, genetic modified organisms (GMOs), disease resistance, nutrient composition.

1. Introduction

Plant genetic engineering plays a vital role in the field of agriculture. Although crop yields have increased globally in recent years, numerous abiotic factors, including salt, drought, cold, and heavy metal pollution continue to hinder the crop growth in different regions. The use of technology to alter and manipulate an organism's genes is known as genetic modification. This term refers to a group of methods that are used to alter the genetic construction of a cell, including the gene transfer that happen within and throughout the species borders in order to create a better and entirely new organisms.

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DNA is generally inserted into an organism's genome as part of GM technology. New DNA is introduced into plant cells in order to create a GM plant. The cells are typically cultured using a tissue culture method, after which they transform into plants. The modified DNA will be passed through the seeds produced by the plants.

The genome is an organism's genetic framework and is made up of DNA, which is present in all plants and animals. Genes are sections of DNA that typically involve the instructions for formulating proteins. They can be found all over the genome. These proteins provide its unique characteristics to the plant. For instance, genes that provide the information for building proteins are necessary to produce pigments that give colour to the petals are responsible for determining the colour of flowers. The recent advancements in molecular genetics as well as genetic modification are transforming the mankind. The application of biotechnology to alter plant genomes is considered as a novel way of providing greater value to promote sustainable food production, materials, energy, or even therapeutic components will be considered as one of the main features.

2. Genetic Engineering

Introducing, removing, or rearrangement of particular genes in an organism by utilizing molecular biology techniques are known as recombinant DNA approaches, which are capable of enabling different and innovative characteristics. Few terminologies related to plant based genetic engineering are listed below:

Genetically engineered organism: An organism created by genetic engineering.

Genetic modification: The process of producing heritable modifications in plants or animals for particular uses, either through genetic engineering or other conventional techniques. The organism produced through genetic modification is known as **Genetically Modified Organism (GMO).**

Genome: The genes that make up all living things, including plants, animals, people, and microorganisms like bacteria and viruses, determine its behaviour. The genome of an organism is considered as the genetic foundation for reproduction [1].

Figure 1. Relationship between genes, DNA, chromosomes and cells

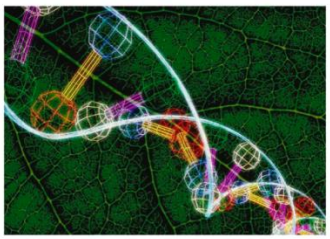
Genetic engineering in plants: The most widely used Genetically Engineered (GE) features enable plants to make their own pesticide, which lowers crop losses due to insect attack, or to resist herbicides, which enables herbicides to kill different types of weeds without damaging the crops.

Example: In the recent past, cotton, soybeans, and corn have all been genetically modified. Over 93% of soybeans, 80% of cotton, and 80% of corns are genetically modified. The ability of crops to fight against pests is improved by altering their genomes. This may reduce the use of potentially dangerous pesticides that are harmful to both the plants and environment. Bacterial gene can be injected into the crop by using genetic engineering. The insects become affected and die when they consume plants that are subjected to bacterial gene [2].

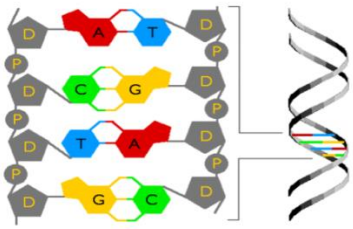
3. Making of Genetically Modified Organism

GMOs are organisms that utilize genetic engineering techniques to introduce some modifications. Discovery of an interesting trait, isolation of trait, insertion of that feature into a desirable organism, and propagation of that organism are considered as the main phases in the field of genetic engineering. Over the past century, the genetic modification techniques have advanced quickly, moving from straightforward selective breeding to the insertion of genes from one creature into another by directly modifying the genome [3][4].

Step 1: Identify a desirable trait: Scientists first decide what characteristics they want a GMO plant to exhibit, such as drought resistance, herbicide resistance, or insect resistance. Then, they discover a living thing (a plant, an animal, or a bacterium) that has the gene for that characteristic.



Step 2: Isolate and make duplicate: Parallel analysis is used to determine the specific region of an organism's genome that is responsible for the desired attribute. Researchers duplicate the gene after they isolate the desired characteristic.



Step 3: Inject: The gene is then inserted into the plant's DNA by using different tools and continue the process.

Step 4: Grow: Once a genetic trait is successfully inserted into an organism's genome, the altered organism must next be capable of growing and replicating with the newly engineered genome.

By modifying their genetic framework, GM plants are intended to develop crops with enhanced characteristics. GM preforms this task by introducing a new genome or genes into the genetics of the selected agricultural plant.

Table 1. Genetically Modified Crops Vs Non-Genetically Modified Crops

Genetically Modified Crops	Non-Genetically Modified Crops
Crops are genetically modified by manually introducing a completely new gene(s) into an organism.[5]	In order to produce an improved progeny, two different plants are mated. Plant breeding requires sexual reproduction.

3.1 Genetically Modified Cotton Crop

- Bollworms frequently attack cotton plants and damage the cotton buds and bolls, and also make the crop unproductive.
- No crossable plant or cotton variety carries a gene for resistance against pests or other bacteria that destroy the crop production. Since cotton variety doesn't have the efficiency to fight against pest, Cross breeding is considered as the solution for the issue of bollworm in cotton.

Figure 2. a) Cotton balls that are damages by Bollworms b) Bt cotton balls.

- There comes the application of GM technology, Bt-Bacillus thuringiensis is a particular type of gene that has been extracted from the soil barium and injected into the cotton DNA.
- Bt contains crystal-like proteins, which has the ability to kill a particular insect species and other creatures. When an insect consumes Cryproteins, its very own digestive enzymes cause the protein to become toxic. The midgut cells are ruptured by

cryproteins once they bind to certain receptors on the intestinal walls. After their first bite, susceptible insects stop eating the plant shortly. If they have consumed more toxins, they will die in 2 or 3 days. Thus, the produced Bt cotton helps the cotton crop to resist against pesticide attacks. This in turn **increases the crop productivity [6]**.

3.2 GMO Corn

The majority of GMO corn is designed to withstand herbicides or fight insect pests. The GMO corn Bacillus thuringiensis (Bt) produces poisonous proteins for some insect pests but not for people, animals, cattle, or other species. Those proteins, which organic farmers employ to manage insect pests are the same ones that are safe for insects like ladybugs. Insect damage is still prevented by spraying less insecticide with GMO Bt corn. Although a lot of GMO maize is used to make processed meals and beverages, the majority of it is fed to animals like cows and poultry animals like chickens [7].

3.3 Fast Growing Trees

Genetically modified trees have been studied for almost as long as genetically modified crops, and some of these trees have been created in laboratories. Poplar, pine, and eucalyptus are the most frequently used species in industrial plantations. The majority of the research has been done on these species with a focus on engineering traits that might leverage various advantages, such as disease resistance, pest resistance, herbicide resistance, high storability, and faster growth. They have matched the growth of GMO crops in this, and they have received similar criticism [8].

Disadvantage: They only have a short lifespan before dying in fall. Trees offer food and protection to animals including insects, fungus, birds, and mammals as per agro ecosystem. The trees have a long lifespan, which equates to a lot of close encounters with the natural environment.

3.4 Golden Rice

Golden rice is a nutritional and genetically engineered grain. Crops with bio fortification will have higher nutritional value. Beta-carotene, which is not typically found in rice is produced by genetically modified golden rice. As beta-carotene is digested by the human body, vitamin A is produced. Healthy skin, immune functions, and vision depend on vitamin A.

*Advantages***:** Golden rice holds the potential to reduce the sufferings of both children and adults in developing nations who have VAD and micronutrients malnutrition as well as assist save millions of lives. The main advantage of golden rice can be improved by enabling various developments in genetically engineered and biofortified crops to fight micronutrient deficiencies in the underdeveloped nations. The technology might potentially be important in the international campaign against deficiency of vitamin A in underdeveloped nations.

Disadvantages: Many anti-GMO campaigns warn about the potential consequences of growing and eating golden rice. Risks include allergic reactions and reduced antibiotic resistance. .

Figure 3. Traditional rice Vs Golden rice.

3.5 Purple Tomato

Gene products obtained from snapdragons have been inserted into tomato plants for increasing the anthocyanin content in the vegetable. The deep purple pigment of tomatoes is a result of anthocyanins, which are also linked to a wide range of health benefits. These tomatoes have the ability to produce ten times as many antioxidant as conventional tomatoes provide as a result of gene editing.

Impact: The study examined the potential health benefits of tomato with the increased amount of anthocyanin by using cancer-prone mice as test subjects. Researchers discovered that mice have fed a meal enhanced with purple tomatoes lived 30% more than mice on a regular diet.

Figure 4. (a) GMO purple tomato (b)GMO Vs Normal tomato

The below table illustrates the functions of genes on various crops and its impacts.

Table 2: GM crops and functions

Crops	Gene source	Method	Impact
Soy Bean	Streptomyces viridochromogenes-	Gene hybrid modification	Tolerance to the pesticide glufosinate
Potato	Solanum tuberosum	Transformed plants through mediation	Modified carbohydrate or improved starch qualirt
Eggplant	Escherichia coli	Mediated transformation	Antibiotic resistance and Lepidopteran insect resistance
Apple	Malus domestica	Mediated plant transformation	Non-Browning, Antibiotic resistance
Eucalyptus	Arabidopsis thaliana	Mediated plant transformation	Wood Volume Increase

Sweet pepper	Cucumber Mosaic Cucumovirus	Mediated plant transformation	Resistance to viral disease
Wheat	Helianthus annuus	Mediated plant transformation	Tolerance for drought
Papaya	Papaya ringspot virus	Bombardment of plant tissue or cells with tiny particles	Viral disease resistance , Visual marker, Antibiotic resistance
Sugar Beet	Agrobacterium tumefaciens strain, Escherichia coli, Ochrobactrum anthropi strain LBAA	Mediated plant transformation	Tolerance towards herbicide
Alfalfa	Agrobacterium tumefaciens strain	Cross hybridization	Tolerance towards herbicide

4. Advantages of GMO crops

4.1 Health Benefits:

The evolution of insect-resistant agricultural types has begun to increase the chances for enhancing human health by lowering the cancer incidence. Pest infestation to the crops has increased the risk of delivering negative health impacts before Bt crops, and maize in particular, as they were industrialized.

4.2 Farmer benefits:

Herbicide-tolerant GMO crops enable farmers to control weeds without sacrificing their crops. Farmers do not need to till the soil in order to get rid of weeds, when they employ

the herbicide-tolerant crops. They are more tolerant to drought, weeds, and insects than conventional crops, requiring lower water and fewer chemical applications. The crops have the potential to grow in salty soil [11].

4.3 Environmental benefits:

GMO agricultural cultivation has reduced CO2 emissions. GMO, One of the techniques farmers employ to cultivate the crops, feeds the globe while leaving sufficient land for human habitation. Farmers can produce better crops within a less area since GMO crops directly address problems like insects; weather, diseases, and food waste. Subramanian and Qaim has analyzed the advantages of Bt cotton growth in India and found that it reduced the pesticide consumption by 41%.

4.4 Economic benefits:

Overall, the impact of GMOs on the economy is significant. Farmers earn more through GMO cropping. Vegetable seed sales have also increased by 40% in the last fiscal year and the hybrid rice seed sales have also increased by 60%. Predictions for a good monsoon, particularly in northern India, where states such as Haryana and Punjab are advising farmers to choose maize, improve the cropping pattern. [12].

5. Challenges in GMO crops

- Some people are campaigning the negative consequences of consuming GMO food that it can alter human genetics. But whether a food is genetically modified or not, the majority of its DNA is either eliminated by cooking or degrade before it enters into the large intestine. Although many research studies are ongoing to establish that GMO crops are unhealthy.
- Allergic reaction is the most frequent negative impact of eating GM food in human beings.
- Additionally, GM food may produce more poisons at levels that are already dangerous to humans. This could be the result of toxins created during the insertion procedure if the "Gene of Interest" is damaged [9].
- GM crops can also result in environmental issues. The main example is Bt corn, in which -A gene in the soil - bacterium Bacillus thuringensis will create specific protein poisons, which can kill pests and insects like caterpillar larvae.

6. Regulations towards GMO crops in India

- Rules for the manufacture, use, import, export and storage of hazardous micro-organisms / genetically engineered organisms or cells, the rule introduced in 1989 issued under EPA include the full range of GMO-related activities, such as purchasing, storing, exporting, importing, producing, manufacturing, packing, etc. Food items have lately been removed from the scope of the rules, 1989.
- Plant Quarantine Order 2003 (Regulation for the import in India)- regulates the import of genetically modified organisms (GMOs) and genetic plant products for research purposes.
- Biological Diversity Act, 2002 - Controls the usage of biological resources, including the genes that are used to modify crops and livestock genetically.
- The Food Safety and Standards Act, 2006 - Controls the production, distribution, sale, and import of food, especially GM food.[10]

7. Conclusion

Genetically modified crops are organic entities in which genetic material has been changed through genetic engineering. Crops that have undergone genetic engineering processes to modify their DNA possess unique traits, these are referred to as genetically modified crops. So far, 525 distinct genetic occurrences in 32 crops have received approval for international cultivation. It has also been demonstrated that the introduction of transgenic technology increases crop yield, decreases insecticide and pesticide utilization, lowers CO_2 emissions, and lowers food production costs thereby increasing the production quantity. The frequent production of GMO crops results in different health and environmental effects. To reduce its negative impacts, new alternative transgenic techniques are on the development process and different regulations are passed to monitor the genetic impact of GMOs.

References:

[1] https://www.usda.gov/topics/biotechnology/biotechnology-glossary

[2] https://www.fda.gov/food/agricultural-biotechnology/how-gmo-crops-impact-our-world

[3] https://sitn.hms.harvard.edu/flash/2015/how-to-make-a-gmo/

[4] https://www.fda.gov/food/agricultural-biotechnology/science-and-history-gmos-and-other-food-modification-processes

[5] https://passel2.unl.edu/view/lesson/7f79e74ec2cd/9

[6] https://www.ars.usda.gov/ARSUserFiles/oc/np/btcotton/btcotton.pdf

[7] https://pubs.acs.org/doi/10.1021/acs.jafc.9b01524

[8] https://www.isaaa.org/gmapprovaldatabase/cropslist/default.asp

[9] https://www.bioexplorer.net/disadvantages-of-genetically-modified-foods.html/

[10] https://bmcproc.biomedcentral.com/articles/10.1186/s12919-018-0106-0

[11] https://www.wired.com/story/future-food-will-need-gmo-organic-hybrid/

[12] Wang, Xingchun, Shujun Chang, Jie Lu, Rupert Fray, Don Grierson, and Yuanhuai Han. "Plant genetic engineering and genetically modified crop breeding: history and current status." *Frontiers of Agricultural Science and Engineering* 4, no. 1 (2017): 5-27.

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