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Review paper

Genetic Engineering Its Application, Importance and Future Aspects in Modern Crop Improvement

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Society is undergoing dramatic transformations as a result of advances in molecular genetics and genetic manipulation. The most widely used genetically altered features allow plants to create their own pesticide, decreasing crop losses due to insect attack, or to resist herbicides, allowing herbicides to be used to kill a wide range of weeds without damaging crops. Those characteristics have been included into most soybean, corn, and cotton types. Genetic engineering could be applied in a wider range of crops, in new methods other than herbicide and insect resistance, and for a wider range of applications. Many farmers that employ genetic engineering crops report that weed control is more cost-effective and that insect pest losses are lower. Traditional methods of breeding and selection to improve crops for intended goals have various advantages over Genetic modification technology. The technology is extremely valuable to society because it provides a variety of benefits. The fact that the area under cultivation of GM crops is rising exponentially each year can be used to measure the success of GM technology. It opens up new possibilities for crop plants to be engineered with novel features. However, the use of GM crops has become a highly contentious topic in recent years, with its roots in misunderstandings and a lack of scientific evidence. This debate, on the other hand, is helping to fuel research in other fields. As a result, a number of techniques for removing marker genes from transgenic plants have been developed. The objective of this paper is to review genetic engineering, its application, and importance and future aspects in modern crop improvement.

Keywords: Genetic engineering, crop, GMO, technology, importance

INTRODUCTION

Increases in crop yields on the same amount of land are becoming increasingly important as the world population grows (Bruinsma, 2009). Furthermore, growing emphasis on food safety, sustainability, reduced agricultural inputs, and pesticide reduction puts additional strain on crops and growers. As a result, some people have turned to genetically modified crops to satisfy the demands of a changing world (National Research Council, 2010).

Thanks to advances in molecular and cellular biology, scientists can now use genetic engineering to bring desired features from other species into crop plants (Conner and Jacobs, 1999). The science of crop development entered a new area with the introduction of genetic engineering technology in agriculture. The capacity to transfer genes between species is a significant step forward from prior plant breeding approaches, which could only transmit desirable features between plants of similar types (Phillips, 2013).

The term "genetic engineering" refers to the deliberate manipulation of genes (such as gene transfer between animals or alterations in a gene's sequence) (Altman and Hasegawa, 2011). Genetic engineering is a sort of genetic modification that entails using recombinant deoxyribonucleic acid (rDNA) technology to make an intended targeted change in a plant or animal gene sequence to achieve a specified result (Sprink et al., 2016). The technique of manually adding additional DNA to an organism is known as genetic engineering, sometimes known as genetic modification (Bruce and Bruce, 2014). The goal is to add one or more new features to that organism that aren't already present. A genetically modified organism (GMO) is an organism that has been created via the use of genetic engineering

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(Snow et al., 2005). Agricultural difficulties caused by biotic and abiotic stressors can be solved with recombinant technology (Sprink et al., 2011).

The majority of genetically modified crops are used for animal feed, processing, or fuel generation rather than being consumed directly by people (Masip et al., 2013). Although there are no new risks associated with eating GMO crops, consumers who want to avoid all foods resulting from genetic engineering can purchase certified organic or GMO-free goods (Bawa and Anilakumar, 2013)

GM crops have the potential to increase crop productivity significantly. The crops can also be utilized to prevent environmental deterioration and to address specific ecological and agricultural challenges that haven't responded well to traditional plant breeding and organic or conventional farming methods [47]. Gene technology provides growers with new options in the form of new products derived from existing species (Halewood et al., 2018). Therefore the objective of this paper is to review genetic engineering, its application, and importance and future aspects in modern crop improvement.

Definition and History of Genetic Engineering

The term "genetic engineering" is commonly used to refer to recombinant DNA technology methods that originated from fundamental microbial genetics research. The artificial manipulation, modification, and recombination of DNA or other nucleic acid molecules in order to transform an organism or population of organisms is known as genetic engineering (Nicholl, 2008). The study of genetic transformation (changing an organism's genetic features by introducing a specific piece of DNA from another source) began with bacteria (Griffiths andStotz, 2013). Griffith demonstrated that genetic traits could be artificially transferred from heat-inactivated cells to live cells and that the alteration could be passed down through generations. DNA is the chemical component that determines a person's genetic features (Chen et al., 2021).

Plants that have had their genetic material (DNA) purposely changed in the laboratory to generate a certain advantageous outcome are known as genetically modified crops. GMOs, or genetically modified organisms, are a term used to describe these types of crops. Limited and precise genetic alterations in commercial genetically modified crops are meant to give one or more benefits to humans or the environment (Islam et al., 2020).

Genetic engineering is a sort of genetic alteration that entails using rDNA technology to make a targeted change in a plant or animal gene sequence to achieve a specified result (Eckerstorfer et al., 2019). Genetic engineering, a sort of genetic manipulation that has been at the heart of many recent improvements in breeding technology, is one such biotechnology method. Genetic engineering, like any new technology, bears some risk and necessitates methods for predicting and assessing potential unintended consequences, whether negative or positive (Wolfenbarger and Phifer, 2000).

Genetic engineering techniques have resulted in the development of medically essential goods such as human insulin, human growth hormone, and the hepatitis B vaccination, as well as genetically modified species such as disease-resistant plants (Khan et al., 2016). Originally, genetic engineering refers to a variety of approaches for altering or manipulating organisms through the processes of heredity and reproduction. As a result, the term encompassed both artificial selection and all biological technological interventions, including artificial insemination, in vitro fertilization (e.g., "test-tube" babies), cloning, and gene manipulation (Bowring, 2003).

However, by the late twentieth century, the word had come to apply more explicitly to recombinant DNA technology (or gene cloning), in which DNA molecules from two or more sources are joined either within cells or in vitro, and then put into host species where they can multiply (Chawla, 2011) The discovery of restriction enzymes by Swiss scientist Werner Arber in 1968 paved the way for recombinant DNA technology. Stanley N. Cohen and Herbert W. Boyer, two American biochemists, were among the first to break DNA into fragments, rejoin them, and implant the new genes into E. coli bacterium, which then proliferated (Rogers, 2015).

The totipotency (capacity of a single cell to regenerate into a completely new individual) of plant cells, which was demonstrated in plants in the 1950s by FC Steward and others, is required for the regeneration of transformed plants from cells receiving the additional DNA (Krishnamurthy, 1999). Over the last two decades, GM crops have gone from proof of concept to a critical component of crop enhancement (Saini et al., 2020). Between 1996 and 2015, the total area of GM crops farmed in the world expanded from 1.7 to 179.7 Mhm2, accounting for around 13.2% of all arable land. Alfalfa, canola, cotton, maize, papaya, potato, soybean, squash, and sugar beet are some of the most widely produced GM crops.In 2015, the top ten countries cultivating "biotech crops" accounted for 89 percent of the GM crops planted out of the 28 countries that did so (Brankov et al., 2016).

Steps of genetic engineering

Genetic engineering is accomplished in the following basic steps.

1. Isolation of the gene to be cloned (target DNA).
2. The gene is inserted into another piece of DNA called a vector, which permits it to be taken up and copied by the recipient cell.

3. Infection of recipient organisms' cells with recombinant vectors, either by transfection or by virus infection.
4. Identifying which cells contain the appropriate recombinant vectors.
5. The changed organism's growth.
6. Gene expression to produce the desired result

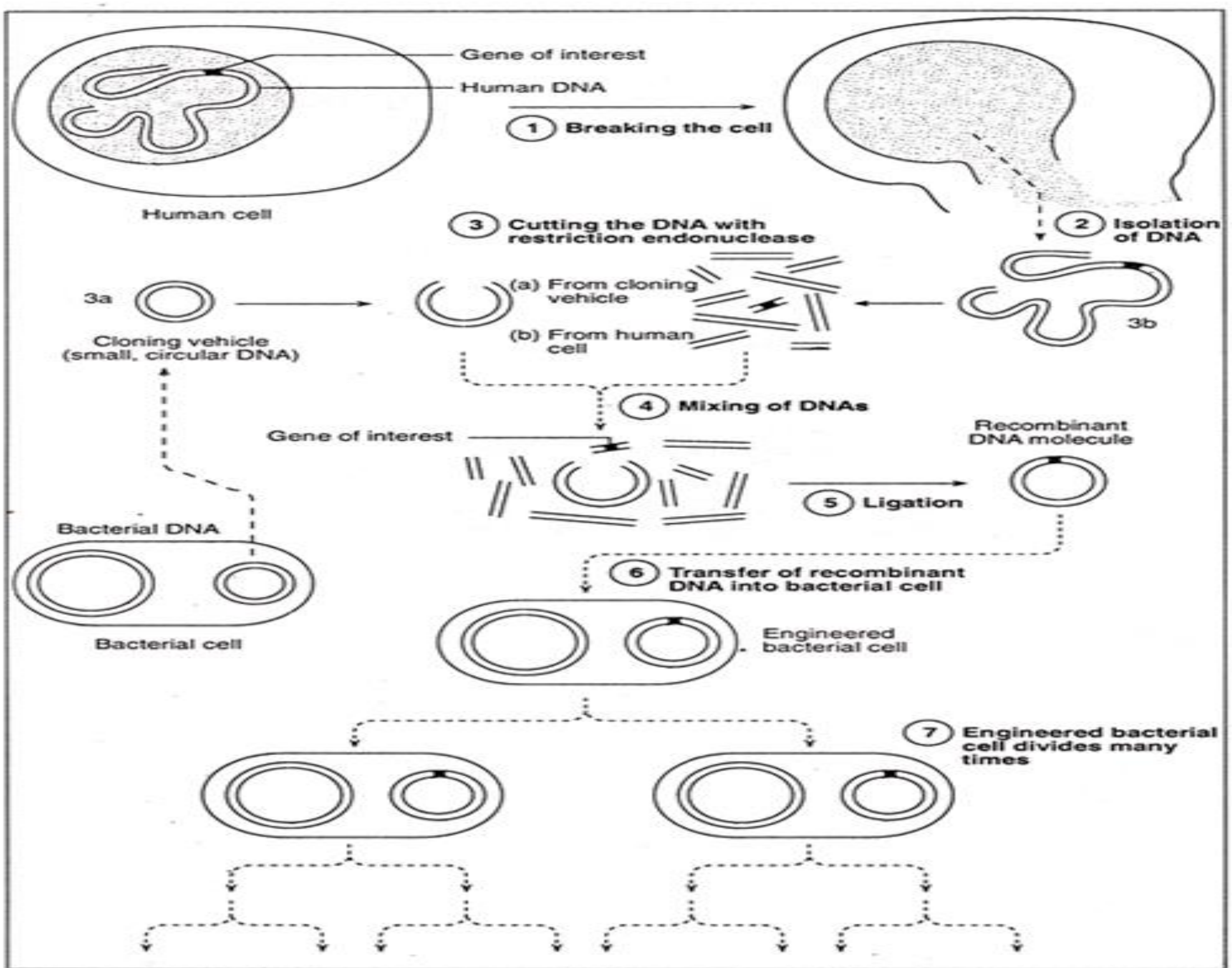

Fig. 22.2: Basic methods of genetic engineering and gene cloning

Application of genetic engineering in crop improvement

Since World War II, the application of genetics to agriculture has led in significant improvements in the production of several crops. This has been especially noticeable in hybrid maize and grain sorghum strains. At the same time, crossbreeding has resulted in artificial selection or selective breeding, which has resulted in considerably more productive wheat and rice variants. These techniques have evolved into subsets of the larger and more contentious area of genetic engineering. The development of strategies for purposely modifying the functioning of genes by influencing DNA recombination has piqued the interest of plant breeders. Researchers have been able to focus on developing plants with characteristics such as the ability to use free nitrogen or the ability to fight illnesses that they did not have naturally (Tansey, 2012).

Many theoretical and practical aspects of gene function and organization have been improved thanks to genetic engineering. Bacteria capable of manufacturing human insulin, human growth hormone, alpha interferon, a hepatitis B vaccine, and other therapeutically important compounds have been developed using recombinant DNA technology (Khan et al., 2016). Plants can be genetically modified to fix nitrogen, and genetic illnesses can be treated by replacing faulty genes with ones that work normally. Toxin-producing genes have been inserted into various plant species, including corn and cotton. Crop plants have also been inoculated with bacterial genes that give herbicide resistance. Other attempts at plant genetic engineering have tried to improve the plant's nutritional value (Halford, 2012).

Uses of Genetic Engineering

Many advantages have been recognized in agriculture through the usage of genetically modified crops. The fast uptake of GM crops in recent years demonstrates the benefits of GM crops to farmers (Mabaya et al., 2015).

Crops Resistance to Virus

The majority of disease control advancements have been in the control of viral diseases, which has piqued biotechnology's interest. Because most viruses are propagated mechanically or through insect vectors, previous management efforts have focused on vector control and the elimination of sick plant components (Reddy et al., 2009).

Plant virus infections have a significant impact on the productivity of a wide range of economically important crops around the world. Control of vector propagation material, suitable cultural techniques, and the use of resistant cultivars are all common ways for managing viral infections. However, as time passes, the procedures begin to reveal flaws. A novel technique to controlling plant virus illnesses has been discovered because to breakthroughs in genetic engineering. Depending on the source of the genes employed, there are primarily two techniques to producing genetically engineered resistance. The genes can come from either the pathogenic virus or another source (Jones, 2004).

Herbicide tolerance

Herbicide tolerance refers to a plant's ability to withstand the effects of a herbicide at the rate that is commonly employed in agriculture. It is a plant's ability to remain unaffected by herbicide application at any reasonable rate (Vats, 2015). Plant scientists now have more tools to figure out the chemical and genetic mechanisms of action of many of these herbicides, as well as the mechanisms that account for a plant's natural tolerance or resistance to herbicides, thanks to biotechnology. As a result, scientists are using this information to develop herbicide-tolerant crop plant varieties (Schütte et al., 2017).The genetic development of crop tolerance to herbicides was one of the first commercial applications of biotechnology. Monsanto's Roundup Ready Soybean has been a great success story in this area (Phillips, 2008).

Higher profit

The promises of improved production and cheaper input costs are currently the key attractions of genetically modified crops for farmers. Crops that are disease and insect resistant require less spraying. Farmers' revenues are frequently higher with genetically altered crops. Larger profits provide greater food security and a better quality of life for farm families in affluent countries, whereas higher profits mean greater food security and a better quality of life for farm families in poor countries. As a result, significant chemical, labor, and energy input costs are reduced. Weed control is improved with herbicide-tolerant crops, which boosts productivity. Growers boost their marketing possibilities by providing higher-quality food to processors and consumers (Huang et al., 2008). Crops that have been genetically modified to have high levels of beneficial oils can be developed (Sprague et al., 2017).

Enhancing the value of crops

Crop genetic engineering has the potential to provide food with health benefits that go beyond basic nutrition. To combat food allergies, genetically modified crops are being created. Many other types of crops, including those resistant to herbicides and pests, as well as those resistant to viruses, are now being created. Crops that are designed to create important pharmaceutical ingredients that are optimized for renewable energy provide additional benefits, such as enhanced nutrition and quality features, drought tolerance, or those that are meant to produce valuable pharmaceutical ingredients. A vast number of GM crops with improved nutritional qualities have been produced and will soon be available on the market (Zhang et al., 2016).

The Golden Rice is one of the most well-known qualities that will provide reinforced rice meals. Gene technology will aid food processors by improving the processing qualities of food. Barley with improved malting properties and altered enzyme activity, for example, could be a future breakthrough. Processing could also improve in terms of efficiency, productivity, and environmental friendliness (Baik and Ullrich, 2008).

Many enhancements to the plant and animal meals we eat are possible because to gene technology. Taste, texture, appearance, consistency, storage properties, and nutritional content are all likely to be improved. Nutritional quality will be the most important enhancement of these traits. Changes to fat, protein, and vitamin content, the development of designer oils and starches, the removal of allergens, and the decrease of anti-nutritional elements were all mentioned in submissions to the inquiry (Altman and Hasegawa, 2011).

The technology may be able to supply nutrients that can help people overcome deficits and lower their chance of developing certain diseases. Food can have different contents and health consequences depending on the structure of essential components. Natural antioxidants, which are vital in atherosclerosis and cancer resistance starches, which are crucial for gut health and colon cancer fatty acids, which are significant in cardiovascular disease (Bryan, 2018).

Other research initiatives involving breeding or genetically modifying crops for nutritional fortification, such as cassava, potato, maize, beans, and so on, are underway. With the latest breeding technology at available, it is apparent that biofortification will transform the food security landscape in the developing countries (Knijnenburg, 2015). Toxic chemicals can be found in both conventional and organic diets. Plants produce several of these chemicals naturally as they grow. Others form as a result of food processing. Natural toxins, such as mycotoxins, can be found in much lower concentrations in genetically altered crops, which can have major health consequences (Zhou et al., 2020).

Environmental benefits

Transgenic crops offer a way for crops to adapt to climate change, especially in terms of drought and salinity. Transgenic crops can also help to mitigate climate change by lowering the intensity of input consumption (Anderson et al., 2020). Genetically modified crops are an important tool for reducing agriculture's reliance on non-sustainable resources (such as wasteful pesticide and fertilizer use, and the possibly damaging impacts of mechanical weeding) and replacing them with biological knowledge packed in the seed (Rhodes, 2012).

In some crops, the use of genetically altered varieties can help to expand no-tillage agriculture. Some insecticide-free genetically engineered crops encourage the growth of natural foes of damaging insect pests (Snow et al., 2005). Genetic engineering could be one of the biotechnology approaches for generating drought-resistant crop varieties (Fita et al., 2015).

Herbicides are used instead of tillage to decrease soil erosion and degradation. Reduced tillage also improves organic matter and reduces carbon loss from the soil. Global warming induced by the emission of carbon dioxide from the soil is reduced by preserving carbon in the soil (Karlen and Cambardella, 2020). Another potential environmental benefit is that genetically modified crops will minimize the need for land clearing by permitting more efficient use of farmed area, so preserving native vegetation and biodiversity (Bertola et al., 2021).

Impacts of Genetically Engineered Crops

Herbicide-tolerant genetically modified plants allow for more widespread herbicide use than traditional kinds. This is already occurring, and it may contribute to a loss of diversity among all types of life on land, as well as in the water and soil near genetically modified plants. Crop plants that are herbicide tolerant are more prone to escape into the wild. Pollen drift from herbicide-tolerant crops to similar wild species, such as canola, could lead to the emergence of ‘super weeds;' this has already happened in a few situations (Parray et al., 2019).BT is always present in genetically engineered crops, whereas it is only present on rare occasions when applied as a spray; it is anticipated that the pesticide's constant presence may lead to a faster accumulation of pest resistance and more harm to non-target and beneficial insects (Veres et al., 2020).

If crop plants that are better suited to marginal agricultural areas are produced, more native vegetation may be cleared and biodiversity may be lost (Qaim, 2020). If terminator technology is employed, terminator genes may spread to other creatures, resulting in the extinction of species. Monocultures are used to raise genetically engineered crops, as well as other modern crops. Because they are extractive and rely on heavy, expensive inputs, monocultures are fragile, unstable, and the antithesis of sustainability (Vinod et al., 2017).

Herbicide-tolerant crops cause a number of environmental problems, none of which are unique to genetically modified cultivars. Both genetically modified and traditionally bred herbicide-tolerant crops have similar environmental implications, and the latter's effects may not be apparent for a long time (Myskja and Myhr, 2020). Over use or misuse of herbicides on herbicide-tolerant crops can have a number of negative environmental consequences: weed species may develop resistance and become ‘super weeds,' which can only be controlled with potentially harmful herbicides; plants that were not previously significant weed species may become new or worse weeds; and the environment may be exposed to higher levels of harmful chemicals, resulting in increased biodiversity loss in the surrounding region (Kumar et al., 2020). Cross pollination with closely related species is another way herbicide-tolerant crops may have an impact on the ecosystem. If the herbicide resistance trait is passed down to wild populations, it may encourage the growth of weediness in those species (MacLaren et al., 2020).

CONCLUSION

Climate change and population pressures are threatening food production; it is critical that we use all available science and technology to secure food security for all. Vaccine- and antibody-based foods, as well as novel protective goods, are expected. Crops with better input features (herbicide tolerance, insecticide and virus resistance, for example) have dominated the market so far. Plant breeders can use genetic transformation to get over limits caused by species barriers. Society is undergoing dramatic transformations as a result of advances in molecular genetics and genetic manipulation.

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Conflict of Interest

The authors declare that they have no competing interests in the paper's publication.

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