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GENETIC ENGINEERING FOR ENHANCEMENT OF CROP PRODUCTIVITY

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Abstract: *The importance of optimal nutrition for human health and development is well recognized. Crop yields are more impacted by adverse environmental factors than by pests and diseases, such as drought, flooding, excessive heat, and so forth. Finding methods to maintain high productivity under stress and developing crops with improved nutritional value are therefore two primary objectives of plant scientists. In order to satisfy the global need for high-quality foods, genetically modified crops may show to be effective complements to those made using traditional techniques. Genetically modified crops can be utilized to raise yields and nutritional quality as well as their tolerance to a variety of biotic and abiotic challenges. There have been some biosafety and health concerns raised in relation to genetically modified crops, but there is no reason to be worried about consuming products that have undergone rigorous development and thorough testing. The objective of achieving food security for both the present and future generations can be accomplished by integrating modern biotechnology with conventional agricultural practices in a sustainable manner. To fulfill the task of feeding the expanding global population, climate change adaptable crops must be developed. By inserting nucleic acid molecules produced by any method outside the cell into any virus, bacterial plasmid, or another vector system to enable their incorporation into a host organism in which they do not naturally occur but in which they are capable of continued propagation, genetic modification refers to the creation of new combinations of heritable material. One of the most common and controversial results of modern biotechnology is genetically engineered organisms. Recombinant DNA technology progress had followed the emergence of genetic mechanisms and biological variability. Recombinant DNA is produced synthetically by combining two or more DNA molecules into a single molecule. By increasing yield and reducing reliance on chemical pesticides and herbicides, genetically modified foods have the potential to address many of the world's hunger and malnutrition issues as well as contribute to environmental conservation and maintenance. Genetically modified plants can help commercial agriculture overcome a number of present problems. One of the most dynamic and innovative worldwide industries, the current market trends project benefits consumers, major national economies, and growers as well.*

Keywords: *Genetic engineering; Food security; Classical breeding; Food safety*

1. INTRODUCTION

In the following 30 years, food production will need to dramatically grow to feed the world. Considering that the present global population of 7.7 billion people is predicted to increase to 8.6 billion by 2030 and 10 billion by 2050, ensuring global food security is one of the century's major concerns (Tomlinson, 2013). Urbanization has increased as a result of population growth, which both directly and indirectly limits our access to agriculturally productive land (Satterthwaite *et al*., 2010). In addition, drought and salinity that restrict agricultural land and water use are caused by the effects of climate change, which also include but are not limited to higher temperature, altered rainfall patterns, and rising CO_2 and ozone levels (Godfray *et al*., 2010).

Malnutrition and food insecurity are currently among the most serious health issues, taking countless lives in underdeveloped nations. Our daily diets need to be rich in high-quality foods that are full of all the nutrients we need to stay healthy, as well as those that have additional health benefits. Due to the ongoing loss of arable lands and the presence of unfavorable environmental conditions like drought, salinity, floods, diseases, and so on, even sustaining the amount of food per capita that we already receive will become an increasingly difficult task in the future. Despite the anticipated unfavorable environmental conditions, the world must produce 50% to 100% more food than it does now in order to ensure food security for future generations (Baulcombe D, 2010).

The use of agrochemicals and high-yielding crop varieties developed through conventional plant breeding procedures resulted in a major increase in crop productivity in India during the green revolution of the middle of the twentieth century. But conventional plant breeding is no longer sufficient to meet the expanding demand for food around the world. The moment has come to fight for sustainable agriculture methods that will increase crop yield while conserving all of the natural resources under our control. In order to meet the need for high-quality food on a global scale, agricultural biotechnology is proving to be a potent supplement to conventional methods. Scientists have now access to large gene pools that can be used to confer desirable traits on economically significant crops due to the new plant biotechnology technologies. Researchers can meet the demand for high-yielding, nutritionally balanced, biotic, and abiotic stress-tolerant crop varieties with the help of genetically engineered crops (Datta A, 2012). Concerns have been raised about the unintended and unanticipated pleiotropic effects of these crops on human health and the environment, despite the fact that the worldwide area covered by genetically modified crops continues to grow every year (James C, 2011).

However, there is no difference between novel foods produced using conventional or genetic engineering techniques in terms of potential unanticipated negative impacts on human health and the environment (Ronald P, 2011). In reality, breeding has altered genomes to a much greater amount than genetically engineered crops have. In two key aspects, genetic engineering varies from previous methods of genetic modification: (1) genetic engineering can introduce genes from any species into a plant, and (2) genetic engineering can introduce one or a few well-characterized genes into a plant species. Contrarily, the majority of the existing methods of genetic alteration, such as forced interspecific transfer, forced selection, random mutagenesis, marker-assisted selection, and grafting of two species, introduce numerous uncharacterized genes into the same species. Genes can sometimes be transferred between species through conventional modification, such as between wheat and rye or barley and rye.

The process of genetically modifying organisms by the transfer of genetic material from one organism to another in order to change an organism's characteristics to the desired traits is known as genetic engineering. An organism (plant, animal, or microorganism) whose genetic makeup has been altered using gene or cell techniques of modern biotechnology is known as a genetically modified organism (Ssekyewa and Muwanga, 2009). Recombinant DNA (rDNA) technology, often known as genetic engineering, is the process of deliberately transferring genes or gene fragments from one organism to another in order to confer novel traits on the recipient living organism. The branch of biotechnology known as genetic modification deals with altering living organisms' genetic makeup so that they can carry out particular tasks (Zhang *et al*., 2016). Recombinant DNA technology is used in genetic engineering to alter an organism's genetic makeup in order to produce target organisms with desirable characteristics.

Crops that have had changes made to their DNA through genetic engineering techniques are known as genetically modified crops, often referred to as genetically engineered or bioengineered crops. In comparison to previous techniques like selective breeding and mutant breeding, genetic engineering techniques allow the introduction of new characteristics from one organism to another organism for significant improvement over the currently existing traits (Lawlor, 2013). By shifting the emphasis away from the paradigm of identifying superior varieties and toward the identification of superior combinations of genetic regions and management techniques, genetic engineering is an improvement program that increases the efficiency of crop improvement in comparison to conventional phenotypic selection.

Plant biotechnology makes it easier to grow crops that have a variety of long-lasting resistances to diseases and pests, especially without the use of pesticides. To feed the globe and free up area for the preservation of plant biodiversity in natural environments, high yielding crops will need to be developed with the use of transgenes or marker-assisted selection (James, 2009). Therefore, crops should be modified to satisfy consumer preferences and needs. Globally, population growth is frightening, yet production issues have a negative impact on productivity. Therefore, the significant problems the world is experiencing cannot be solved by using standard plant breeding techniques alone. Thus, conventional plant breeding should be supported and merged with diverse biotechnology breakthroughs to speed up the crop genetic enhancements in order to address the issues with food security. Genetic engineering must be used into plant breeding in order to assure rapid and sophisticated agricultural progress in a short amount of time.

The potential benefits of genetically modified crops include increased agricultural productivity and a decrease in the use of pesticides that are damaging to the environment. Genetically modified crops are intended to increase productivity, increase crop tolerance to environmental challenges, and protect crops from pests, as well as to give food a higher nutritional value. Plant breeders can now alter plants in unique ways due to genetically modified crops, which has the potential to solve significant issues in contemporary agriculture. Using agrobacterium as a biological vector and direct gene transfer techniques, genes can now be introduced into plants. Although agrobacterium-based methods for transferring genes are more effective than other approaches, they have the drawback of not being suitable to everyone plant species (Christou, 1995). Thus, some have turned to genetically engineered crops as a way to meet the demands of a changing world. The objective/s of the paper was to understand the role of genetic engineering in agricultural crop enhancement and the efficiency of crop improvement relative to conventional breeding program to produce new superior varieties for desirable agronomic characteristics.

2. Genetically Modified Crops versus Classically-Bred Crops

Plant biology study attempts to increase crop productivity, resistance to biotic and abiotic stress, and food nutritional levels in order to increase food security. Breeders have been able to create better types of many crops because of conventional breeding techniques; hybrid grain crops, for instance, have significantly higher yields. Emerging technologies have the ability to overcome many of the difficulties that still exist. Crops that have been traditionally bred and those that have been genetically changed are the products of genetic alterations made using various gene transfer technologies. Changes in an organism's genetic make-up with regard to DNA sequences and gene order may occur through both classical breeding and genetic modification technology. However, compared to conventional breeding, where thousands of uncharacterized genes of an organism may be involved, the genetic modifications caused by genetic modification technologies are few and well characterized. Additionally, the end products of genetically modified crops, such as proteins, metabolites, or phenotypes, are well-characterized as a result of very precise and focused genome change. In conventional breeding, the genomes of the parents' respective offspring are combined and randomly rearranged.

As a result, certain genes may be lost in the offspring while other genes may be transferred together with the favorable genes. Plant breeders perform repeated back-crossing to the desired parent to address these issues. This takes time, and it might not always be possible to isolate a harmful gene that is strongly linked. For instance, classically bred potato types yield an excessive amount of naturally occurring glycoalkaloids (Hellenas et al., 1995). These glycoalkaloids result in alkaloid poisoning, which can cause issues with the digestive system, the cardiovascular system, the nervous system, and the skin. Demissidine, a toxin that neither of the parents of the hybrid S. tuberosum nor S. brevidens produces is produced by the hybrid (Laurila et al., 1996). Another example was the conventionally produced high psoralens type of celery, which was discovered to cause skin rashes in farm workers who were engaged in the collection of this crop (Berkley et al., 1986). Therefore, conventional (non-genetically modified) breeding techniques may result in unexpected results and produce new goods that could be dangerous. Contrarily, genetic modification technology uses precise control over the time and position of gene products to provide tissue/organ/development/stress-specific expression and that is challenging to achieve with conventional breeding. Furthermore, unlike conventional breeding, genetically modified procedures allow for the introduction of novel traits all at once without requiring extended cross-breeding. From a scientific viewpoint, foods created through conventional breeding or genetic modification technologies can have the same consequences on the environment and human health.

2.1 Food Security: Addressing Old Challenges And Emerging Threats

Food must offer an adequate supply of calories and nutrients to support life. Malnutrition is a threat to millions of people around the world due to food insecurity, which results from limited access to adequate food supplies. In addition, the issue is getting worse since the world's population is projected to increase to 8.3 billion people by the year 2030. As a result, there will be a rise in the demand for food, animal feed, and fuel (Sundström et al., 2014). Abiotic stress increases brought on by climate change, reductions in arable land due to desertification, salinization, and human use, and developing diseases have joined population growth as a threat to food security. Despite the projected concerns, such as climate change, the globe must double the current crop production rate to improve food security for future generations. To combat food poverty, plant breeders have used both organic and synthetic mutations as well as crucial strategies like breeding for hybrid vigor. However, more effort will be needed to address ongoing and future difficulties.

The goals of current crop yield improvement strategies are to increase food production per cultivated area and to reduce crop failures. Breeders have focused on traits that increase the number of grains produced per plant, the number of plants that can be cultivated per unit area, and the size of each grain in order to increase yield per area in grain crops like rice. Many of these traits require modifying the structure of the plant by coordinating hormone signaling and meristem activity. Breeders have focused on traits that assist crops withstand stressors in order to reduce crop failures and hence increase yield stability. Researchers have focused on the tolerance to heat, cold, high light, high salt, heavy metals, and other challenges when it comes to abiotic stress. Researchers have found loci conferring resistance to various viral, bacterial, and fungal pathogens, as well as loci affecting interactions with animal and plant pathogens, including nematodes and parasitic plants like Striga, for biotic stresses, which have become a greater problem as globalization and weather accelerate the spread of pathogens (Butt et al., 2018). Finding the crucial loci to insert and quickly introducing those loci into elite varieties are the two challenges in disease resistance. Furthermore, it is still challenging to strike a balance between the energy needs for growth and resistance while minimizing yield losses.

Current strategies attempt to provide diverse and balanced diets with adequate levels of vitamins and minerals that improve human health in order to raise the nutritional value of crops. Recent advancements in agricultural biotechnology allow for the manipulation of important enzymes in certain metabolic pathways, increasing the content of essential nutrients like vitamins and iron and decreasing the number of undesirable substances like phytic acids and amino acids that create acrylamide. To address the issue of nutrient inadequacies, several biofortified crops, including rice, maize, and wheat, has been created (Mugode et al., 2014). Golden Rice is a well-known example of genetically modified food that produces a substantial amount of -carotene to aid those who are at risk of vitamin A deficiency (Ye et al., 2000)

2.2 Genetically Modified Crops and Food Safety

In several countries, commercial cultivation of genetically modified crops that were developed by inserting genes for better agronomic performance and/or higher nutrition has begun (James C, 2011). The origin of the DNA used to generate the genetically modified crop has a significant impact on how rigorously food safety considerations are made. Other methods to extend the shelf life of fruits and vegetables involve suppressing the host genes rather than adding a new gene (James C, 2011). Since plant viruses are not known to be human pathogens, the genes produced from them can likewise be regarded as harmless transgenes. Many virus-resistant transgenics have been developed and made available for commercial use, either because they over express siRNAs (Bonfim et al., 2007) or the coat protein (Gonsalves D, 1998). The genetically modified papaya that is resistant to the papaya ring spot virus (PRSV) is a well-known example (Gonsalves D, 1998). Currently, a coat protein from the papaya ring spot virus has been genetically modified into nearly 90% of the papaya grown in Hawaii. The commercial cultivation of this transgenic papaya increased papaya yield significantly. There is currently no conventional or natural way to stop this virulent virus.

After several years of broad genetically modified crop production in various ecosystems and consumption of genetically modified food by more than a billion people and an even greater number of animals, no adverse effects have been observed (Park et al., 2011). Before a genetically modified crop is allowed to be used for commercial production, it is crucial that its performance is closely monitored for multiple generations in the field and that it undergoes thorough bio-safety evaluations. In laboratory animals, thorough research should be done on a variety of allergenicity and toxicity characteristics. It is important to assess the stability, digestibility, allergenicity, and toxicity of expressed proteins. Genetically engineered crops should undergo comparative nutritional profiling.

2.3 Use of Markers, a Biosafety Issue in Genetically Modified Crops

Selectable and storable marker genes are essential for choosing the transformation events that result in the development of genetically engineered crops. Kanamycin and hygromycin resistance genes are two of the most often utilized selectable markers. Concerns about selectable and storable marker genes ' potential for horizontal gene transfer to relevant species and diseases as well as their toxicity or allergenicity are the main biosafety issues that have been brought up. It has been hypothesized that spreading these flag genes to other plants could lead to the emergence of new unwelcome weeds. The selectable marker neomycin phosphotransferase II (NptII), which is most frequently utilized, has undergone the most thorough biosafety evaluation. Studies have shown that NptII is non-toxic and it is not expected to result in increased weediness or invasiveness and it also does not affect the non-target organisms (Petersen et al., 2005).

2.4 Targeted Improvement of Crop Traits

Although genetic engineering is still a young field, it has successfully been used to a variety of crops to increase yield, quality, and nutritional value, herbicide resistance, and tolerance to biotic and abiotic stress (Wang et al., 2016). Advanced sequencing methods in crop species have produced important information on the sequence variation of trait-associated genes, which is crucial for the identification of targets for genome editing. Genetic studies have discovered important loci that are connected to yield. The application of genome engineering for expedited and targeted trait enhancement opens up new prospects for the discovery of advantageous alleles that result in desirable phenotypes. Following are some of the advantages of genetic engineering.

2.4.1 Improving Yield

One of the most crucial characteristics of crop plants is yield. Numerous genes regulate it quantitatively (Bai et al., 2012), and extensive research has been done to identify the quantitative trait loci (QTLs) governing yield in various agricultural plants. Traditional breeding is a labor-intensive approach that was first employed to increase yield and create plants that could thrive in specific growth situations (Duvick, 1984). Breeding involves creating different QTL combinations and choosing the most promising ones to use in further breeding (Shen et al., 2018). Additionally, it is not always simple for QTLs to introgress between distinct types, particularly when the loci are closely related.

2.4.2 Engineering Plant Disease Resistance

Pathogens such as viruses, bacteria, and fungi are continually infesting plants, which can result in considerable losses in crop quality and yield (Taylor et al., 2004). The genetic foundation of plant disease resistance has attracted significant research, and genes involved in disease resistance have been found in a variety of plant species, including Arabidopsis, rice, soybean, potato, tomato, and citrus (Hammond-Kosack and Jones, 1996). Technologies for genome editing have been widely used to create plants that are resistant to diseases (Ji et al., 2015). Candidate genes for disease resistance are those that are involved in plant-microbe interactions and restrict the diseases' virulence features. Using toxins and enzymes that break down cell walls as an example. Such genes that increase the production of plant defense chemicals such as saponins, ROS, phytoalexin, and antimicrobial peptides are introduced to plants. These are antimicrobial proteins that provide pathogens resistance by eradicating their pathogenicity components. Such transgenic gene invasions provide plants with a tolerance to several illnesses (Strange, 2005).

2.4.3 Enhancing Plant Abiotic Stress Tolerance

Abiotic stressors that inhibit plant growth and development, such as drought, salinity, and excessive temperatures, severely reduce food production globally (Pandey et al., 2017). Many of these stresses will get worse under the expected global climate change circumstances, potentially leading to a significant decline in crop productivity worldwide. Through sophisticated defense systems, which typically involve the expression of several stress-inducible genes, plants may tolerate a variety of abiotic challenges (Golldack et al., 2014). Transcriptional factors in particular play a crucial role in gene regulatory networks that regulate the expression of numerous genes involved in stress responses. Our understanding of the intricate structure of abiotic stressors and the connections between signaling, regulatory, and metabolic pathway components has improved as a result of genetic and genomic advances (Mickelbart et al., 2015). Both model plants and agriculturally significant crop plants have

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benefited from the identification of numerous potential candidate genes and their transformation by conventional genetic engineering techniques to increase abiotic stress tolerance (Gong and Liu, 2013).

2.4.4 Enhancing Plant Herbicide Resistance

Crop plants compete with weeds for resources including water, nutrients, light, and space, which significantly lower production. For the control of weeds, a variety of methods have been employed, particularly conventional pesticides and methods based on genetic engineering. Herbicides typically target an important stage in a plant's metabolic process, fully eliminating weeds but also potentially causing significant harm to crop plants. By expanding the global food supply, herbicides help the economy, but they can also be harmful to the environment and the health of people and animals. The development of biotechnology has transformed agricultural methods by making it possible to spread a specific gene for herbicide resistance across a variety of crops (Lombardo et al., 2016).

2.4.5 Improving Food Crop Quality

Numerous different significant traits of plants, such as the starch composition in potatoes (Tahaka et al., 1998), tomato ripening (Klee et al., 1991), lignin content in Arabidopsis (Ni et al., 2008), and flower vase-life in carnations (Bovy et al., 1995) have been altered using transgenic technologies. These modifications have opened up numerous new opportunities for use in both agriculture and industry.

3. CONCLUSION

The use of plant biotechnology could help with a number of issues facing agriculture and society. Genetically modified strategies are used to increase the value of food crops by enhancing them with high-quality proteins, vitamins, iron, zinc, carotene, anthocyanins, and other nutrients. These techniques are also used to reduce yield losses caused by various stresses (biotic and abiotic). To considerably reduce the post-harvest losses of perishable commodities, other continuing projects include extending the shelf life of fruits and vegetables. Even after several years of extensive cultivation in a variety of habitats and widespread human consumption, no negative impacts of these crops have been identified, despite the fact that the worldwide area under genetically modified crops continues to grow every year. Farmers have benefited from the commercial cultivation of genetically modified crops that are herbicide tolerant and insect resistant, as well as from improved yields and less usage of chemical pesticides.

The process of genetically modifying organisms by the transfer of genetic material from one organism to another in order to change an organism's characteristics to the desired traits is known as genetic engineering. An organism (plant, animal, or microorganism) whose genetic makeup has been transformed using gene or cell procedures of modern biotechnology is referred to as a genetically modified organism. By shifting the emphasis away from the paradigm of identifying superior varieties and toward the identification of superior combinations of genetic regions and management techniques, genetic engineering is an improvement program that increases the efficiency of crop improvement in comparison to conventional phenotypic selection. Genetic engineering results in genetically altered organisms, plants, and animals. Biodiversity may be impacted by the introduction of genetically modified crops to the ecosystem. Genetic variety is essential for adapting to new surroundings because it increases the proportion of a population with features that make them more resilient to adverse situations.

This leads to the conclusion that conventional plant breeding and diverse biotechnological techniques should be combined to enhance agricultural genetic development and reduce the crop improvement cycle with desirable traits in order to meet both the quantitative and qualitative needs of the population. Prior to being allowed for commercial production, it is crucial that the performance of a genetically modified crop undergoes extensive bio-safety evaluations and is closely monitored for multiple generations in the field. In order to maximize the potential of biotechnology for the benefit of humanity, genetically modified crops must become an integral part of everyday existence.

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