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A Review on Role of Biotechnology in Agriculture

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ABSTRACT: The increase in human population worldwide has become a major threat to food security. Biotechnology is an interdisciplinary field that deals specifically with many aspects of life with genetically modified medicine, food, global warming and energy production. The agricultural and horticultural sectors are under a lot of pressure because of the rising demand for food, feed, nutrition, and other basic necessities to find solutions to the problems posed by boosting crop productivity. At the same time, we are observing the potential advantages of the revolutions prompted by biotechnology and with utilization of various biotechnological tools, biotechnology has significantly contributed to the achievement of sustainable crop production. Inputs from conventional and biotechnological research have helped to find solutions to some of the problems limiting crop productivity. Crop improvement programs are, however, hampered by factors like a complex genome, a limited genetic base, poor fertility, susceptibility to biotic and a biotic stresses, and a lengthy breeding period for elite cultivars. In this narrative review of literature study, we aimed to describe and delineate on the role of biotechnological applications in the field agriculture.

Keywords: Biotechnology, Agriculture, Micropropagation, Next-generation sequencing.

INTRODUCTION

The increase in human population worldwide has become a major threat to food security. Population growth, particularly in countries with developing economies, will result in the need for a 70% increase in food production by the year 2050 making the significant enhancement of agricultural productivity in the next several decades a priority (Chekol and Gebreyohannes 2018).

Biotechnology is a rapidly developing aspect of contemporary industry, agriculture, and medicine because it can be used to study all genus of organisms, including viruses, bacteria, plants, and animals. In order to comprehend and manipulate organisms' genetic makeup for use in the production or processing of agricultural products, scientists use a variety of tools in modern agricultural biotechnology. In order to solve issues in all facets of agricultural processing and production, biotechnology is being used. In addition to developing new tools for the detection and treatment of plant and animal diseases, biotechnology is being used to develop low cost- and disease-free planting materials for crops (Milu, 2008; Tanaka *et al.*, 2010). Utilizing biotechnology, breeding programs for fish, livestock, and plants are accelerated, and the range of traits that can be addressed is expanded (Fu *et al.*, 2005). Animal feeds and feeding practices are being changed by biotechnology to improve animal nutrition and to reduce environmental waste (James, 2002). Although agricultural biotechnology has the potential to be the most potent and helpful for the poor (Tanaka *et al.*, 2010), it is also used in disease diagnostics and the creation of vaccines against animal diseases. Many value-added starch-based biopolymers and biofuels that are likely to be less harmful to the environment than those made from petrochemicals use cereal starch (Thitisaksakul *et al.*, 2012). With this background in this narrative review of literature study we aimed to describe and delineate on the role of biotechnology in agricultural field.

BIOTECHNOLOGICAL TACTICS

Various biotechnology techniques and strategies have been used to improve the quantity and quality of vegetables. The scientists were inspired by the DNA-based knowledge to successfully isolate the targeted gene of interest, transfer it, and integrate it into the host species. These efforts were made possible thanks to the DNA-based knowledge. Traditional crossing was restricted to closely related species only, but advancements in plant biotechnology have made it possible to improve in ways that traditional crossing cannot. Below, various highlighted techniques and strategies have been succinctly discussed as follows;

A. Genetic Engineering Strategies

The cutting-edge method of genetic engineering can be used to produce vegetables or horticultural crops with the potential for improved quality and productivity. The genetic engineering method entails the genetic modification of a host plant through the insertion of a novel gene that improves the plant's immunity (disease-free), nutritional value, or agronomic performances; these plants are known as genetically modified (GM) plants or GM crops. (James, 2011). The role of genetic engineering has been wide spread due to production of special characterized vegetable crops such as colors, aromas, flavours tastes, sizes, harvest durability, resistance against insects and pests etc. There are mainly two transgenic strategies for improvement of vegetable crops *viz.*, transgenic strategies for biotic stress management and transgenic strategies for abiotic stress management as detailed below;

(i) Transgenic strategies for biotic stress management. Damage to plants are mainly due to biotic stress originated by additional living organisms like insects, parasites, viruses, bacteria, fungi, weeds etc. crop yield losses to a number of 40% despite of the application of insects, pathogens, fungicides, pesticides, herbicides, and weeds (Pimentel, 1997; Meeusen, 1996).

Genetically engineered herbicide-tolerant (HT) crops: In genetically engineered HT crops, a gene from the soil bacterium *Agrobacterium tumefaciens* is used. The broad-spectrum herbicide glyphosate becomes tolerable to the recipient plant as a result. HT crops can aid in weed control and lower production costs. Roundup Ready (RR) is the trade name for a HT crop. In 1996, RR soybeans were made available for purchase (James, 2002a).

Genetically engineered drought resistant crops: The techniques for gene transformation of crop plants have been applied for identification of gene responsible for drought resistance and their transfer. Mainly two approaches, namely targeted and short gun approach facilitate genetic engineering to obtain transgenic plants conferring drought resistance (Khan and Khan 2010).

(ii) Transgenic strategies for abiotic stress management. Abiotic stress is a natural circumstance that reduces crop development and output in an ideal ratio. This includes extremes of heat, salinity, cold, drought, metal toxicity, and lack of nutrients. Abiotic stress is estimated to have reduced crop plants' output by more than 50%. As various processes of transgenic methods engaged for enhancing the immune constrain in plants are the initiation of enzymes encoded by the genes which activate the altering of a normally occurring substrate into a product for osmoprotective belongings and radical-scavenging enzymes, the initiation of genes coding membrane-altering enzymes, or stress-generated proteins (Holmberg and Bülow 1998).

APPLICATIONS OF PLANT BIOTECHNOLOGICAL STRATEGIES

Modern biotechnology represents distinctive applications of science that can be used for the betterment of society through development of crops with improved nutritional quality, resistance to pests and diseases and reduced cost of production and *vice-versa*. The following are given below:

Micro propagation of disease-free plants like banana: In developing nations, where it is a source of food, employment, and income, bananas are typically grown. A method for creating disease-free banana plantlets from healthy tissues is micropropagation. It benefits from being a relatively simple and affordable technology (Milu, 2008).

Agriculture on acid soils: Lime can be added to the soil to raise the pH in order to maintain the soil's pH. This treatment is pricy and short-lived. Alternately, improved cultivars that are resistant to aluminum can be created. When compared to wheat, rye can tolerate aluminum four times better (Kole, 2011).

Fortification of crops: In order to decrease child malnutrition in developing nations, some crops are enriched with nutrients. The genetically modified potato known as "Protato" produced in India produces between a third and a half more protein than typical. It also contains significant amounts of all the essential amino acids, including lysine and methionine. In developing and less developed nations, protein deficiency is common. The cheapest and most common food among the world's poor is the potato (Coghlan, 2003). Similarly, the genetically modified rice known as "golden rice" produces beta-carotene, which is a precursor to vitamin A. Consequently, it can be used to treat the Vitamin A-related vision problem (Ye *et al.*, 2000).

Use of biofertilizers: Crops require a balance of soil nutrients for proper growth because phosphate and nitrogen are two elements that are heavily utilized in metabolism. Biofertilizer is created by coating crop seeds with various organisms, such as Penicillium bilaii, which breaks down phosphate in the soil so roots can easily absorb it, and Rhizobium, which fixes nitrogen. Biofertilizers reduce the use of costly chemical fertilizers and are also environmentally friendly (Yang *et al.*, 2009).

PERSPECTIVES ON PLANT BIOTECHNOLOGY RESEARCH

To meet the never-ending demands of farmers and consumers, plant breeding is crucial to the development, selection, and improvement of crop varieties in the field of plant biotechnology. Micro-propagation has long played a significant part in tissue culture-based in vitro vegetative plant propagation. In comparison to traditional propagation techniques, micropropagation has a number of benefits, such as the preservation of genotype constitution, quick shoot and root multiplication, preparation of virus-free materials, and simpler transportation and storage. Micropropagation methods frequently used include apical meristem culture, axillary and adventitious shoot induction, and regeneration by somatic embryogenesis and organogenesis (Atanassova and Keiper 2018; Singh *et al.*, 2018).

In plant breeding, the ultimate aims are to improve yields, increase the quality or profitable value, and develop resistance against pests or unfavorable conditions. Of the currently used techniques, marker-assisted backcrossing is the most common approach using molecular markers to assist in the selection of new desired varieties. A typical example of plant biotechnology is the use of a toxic protein (Bt) from *Bacillus thuringiensis* to control insects in corn production (Fleming *et al.,* 2018).

Advanced techniques in genome sequencing, especially next-generation sequencing (NGS) and bioinformatic tools, provide huge databases for identifying and understanding the functions of genes (Pérez-de-Castro *et al.,* 2012; Mammadov *et al.,* 2012). Next-generation genome sequencing (NGS) technology enables the sequencing of whole genomes or transcriptomes. SNPs are new targets for tagging and linkage analysis. More recently, the development of genome editing technologies such as transcription activator-like effector nuclease (TALEN), zinc finger nuclease (ZFN), and clustered regularly interspaced short palindromic repeats (CRISPR/Cas9) have triggered the dawn of genome editing (Ju *et al.,* 2018).

To improve the nutritional value of staple crops, genetic engineering can be used to change the amino acid makeup of plant proteins. Soybeans with altered fatty acid profiles and higher levels of essential amino acids are among the crops being developed (Ufaz and Galili 2008); increased sensory qualities in tomatoes and fruits (flavor, aroma, and texture) (Klee, 2010); golden rice which has extra iron and vitamin A (Dubock, 2017); potatoes with more nutritionally available starch and with improved amino acid content (Bagri *et al.,* 2018).

PERSPECTIVES ON CHALLENGES

Numerous agricultural species have had their genomes partially or entirely sequenced in recent years. With the quick accumulation of biological sequences, comparisons of entire genomes or particular regions of interest provide invaluable insight into the characteristics and roles of different genes. Agricultural researchers can close the gap in the relationship between genotype-phenotype and environmental factors thanks to advancements in NGS technologies, which are both cheaper and more effective than previous generations, and "omics" technologies (Ohashi *et al.,* 2015). One could say that the Arabidopsis genome project is currently at the point where it has largely finished determining the functions of all of the plant's genes, interactomes, phenotypes, metabolic pathways, and network controls. It would therefore be appropriate to create technologies to apply this knowledge to other plants, particularly crops. New technologies, particularly in transgenes and gene editing, will be needed as human demands continue to rise, such as the increased nutritional value of grains, decreased allergens and antinutritional factors in food products, extended shelf lives for fruits and vegetables, and higher vitamin and micronutrient contents in cereals (Kamthan *et al.,* 2016).

Genetically modified organisms (GMOs), transgenic crops, and recombinant DNA technology are the future trends in plant biotechnology, but there are many arguments against their widespread commercialization and use. It is also important to understand the functions of genes governing complex traits in order to actively improve agronomic performance or regulate adaptations to abiotic stresses (Maghari and Ardekani 2011). A crop's capacity to thrive in arid, salty, acidic, or aluminum-containing soils, weed competition, flowering time, heterosis, and long-lasting disease resistance are among the complex traits of interest. It would not be unexpected if some of these complex traits were incorporated into crop plants through genetic engineering in the ensuing decades. Additionally, it should be noted that despite numerous research labs having successfully tested gene/genome editing technologies, there is still much work to be done in order to successfully develop new crop varieties with desirable traits for human consumption. However, in light of the world's expanding population and climatic changes, the use of gene editing techniques in crop plants will be the future answer to developing new agricultural development strategies (Maghari and Ardekani 2011; Moshelion and Altman 2015). New methods for producing biofuels, a renewable energy source, are needed due to the depletion of fossil fuels and subsequent rise in energy prices. Biofuels are produced from renewable feedstocks like biomass, by-products of agricultural production, or ethanol from food crops. Lignocelluloses are promising raw materials for enzymatic fermentation and chemical synthesis of biofuels (Den *et al.,* 2018). In order to degrade the stable polymer chain into sugar molecules for additional fermentation and conversion, biotechnology must modify or alter the characteristics of the polysaccharide profile in the cell walls of plant materials (Popa, 2018).

CONCLUSIONS

In conclusion, genetic transformation, and marker-aided selection and breeding are the key applications of biotechnology in agriculture to address the increasing demands in terms of food security, socio-economic development and promote the conservation, diversification and sustainable use of plant genetic resources.

FUTURE SCOPE

Biotechnology provides a range of tools to enhance our knowledge and management of genetic resources for agriculture and food. Thus, biotechnology is crucial to the continued production of food. Additionally, biotechnology applications provide researchers new information and resources that improve the effectiveness and efficiency of their work. The environmental issues that directly or indirectly impact agriculture are also addressed by biotechnology.

Conflicts of Interests. None.

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