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Review Article

Major Achievements of Plant Biotechnology in Crop Improvements

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Abstract: Biotechnology is any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for a specific use. Agricultural biotechnology is the area of biotechnology involving applications to agriculture. Based on an understanding of DNA, scientists have developed solutions to increase agricultural productivity. Integrating recombinant techniques into conventional breeding programs could substantially enhance the efficiency of agricultural research and development. Breeding could be accelerated due to the more targeted transfer of desired genes into the crop. The major transgenic breeding objectives are; improving the agronomic traits and quality traits of different crops. Deliberate alteration of the genome of an organism by introduction of one or a few specific foreign genes is referred to as 'genetic engineering' or 'genetic transformation', and the modified organism is described as a 'transformed' or 'transgenic' organism. Achievements of biotechnology in crops were producing Bt crops, herbicide resistance crops, salinity tolerant crops, drought-tolerant crops and so on. Genetically engineered crop varieties that farmers deploy. Transgenic crops, especially those with resistance to biotic and abiotic stress factors, fit well into small-scale farming systems and can easily be integrated without adjusting traditional cropping practices. The comparatively low setup cost for adopting genetically engineered technologies at the farm level also makes this technology useful for semi-subsistence agriculture. Plant tissue culture also one of the applications of biotechnology used to improve crops and used to increase the speed or efficiency of the breeding process, to improve the accessibility of existing germplasm and to create new variation for crop improvement. Generally, the role of crop biotechnology for food security and poverty reduction should not be overrated. Many problems in low- and middle-income countries are not amenable to technological solutions.

Keywords: Biotechnology, Genetic Engineering, Tissue Culture, Transgenic Crop

1. Introduction

Biotechnology is the application of scientific techniques to modify and improve plants, animals, and microorganisms to enhance their value. Agricultural biotechnology is the area of biotechnology involving applications to agriculture. Agricultural biotechnology has been practiced for a long time, as people have sought to improve agriculturally important organisms by selection and breeding. An example of traditional agricultural biotechnology is the development of disease-resistant wheat varieties by cross-breeding different wheat types until the desired disease resistance was present in a resulting new variety [26].

Agricultural biotechnology is a collection of scientific techniques used to improve plants, animals, and microorganisms. Based on an understanding of DNA, scientists have developed solutions to increase agricultural productivity. Starting from the ability to identify genes that may confer advantages on certain crops, and the ability to work with such characteristics very precisely, biotechnology enhances breeders' ability to make improvements in crops. Biotechnology enables improvements that are not possible with traditional crossing of related species alone.

In the 1970s, advances in the field of molecular biology provided scientists with the ability to manipulate DNA the chemical building blocks that specify the characteristics of living organisms at the molecular level. This technology is called genetic engineering. It also allows the transfer of DNA between more distantly related organisms than was possible with traditional breeding techniques. Today, this technology has reached a stage where scientists can take one or more specific genes from nearly any organism, including plants, animals, bacteria, or viruses, and introduce those genes into another organism. An organism that has been transformed using genetic engineering techniques is referred to as a transgenic organism, or a genetically engineered organism [25].

Most investments in agricultural biotechnology: 1. Have centered on widely consumed crops that are traded internationally, such as maize, rice, wheat, cotton, soybeans, and canola (James, 2001). Neither the public nor the private sector has invested significantly in genetic technologies in the more diverse minor or ''orphan'' crops that are often critical in the world's most disadvantaged regions. 2. Because orphan crops occupy smaller areas and have more limited markets, they are rarely a target of advanced science.

The biotechnology field has seen advancements in the past several decades [24]. Comparatively, it is now a fully mature science and is proud to be on the list of most quickly adopted crop technologies in the world. Biotechnology provides the capabilities to breeders to achieve certain goals that would otherwise be impossible through conventional plant breeding approaches. Globally, today genetically modified crops are grown in fields on a commercial scale. Thus, the biotech crop area has increased from 1.7 million ha in 1996 to 160 million ha in 2011 [14]. This trend was well-expected [9] when he stated that "Genomics (originally DNA- and transcript-based, but recently extended to integrate the proteome and metabolome) would play a major role in driving plant biotechnology''.

Plant growth and productivity are severely affected by abiotic and biotic stresses [1, 10]. Due to the inadequate number of resistance genes, breeding for stress resistance/tolerance in ornamental plants is difficult [2]. During last few years, the use of biotechnological strategies for conferring resistance against abiotic and biotic stresses e.g., drought, pathogen attack have gained attention. The critical appraisal of transgenic ornamental plants indicates resistance to biotic stresses in comparison to the wild plants [6]. Fungal, viral, or bacterial pathogens sternly affect plants by decreasing plant growth and yields [10]. Inclusive of reduced quality of ornamental products. Thus, this paper aimed to review and document the major achievements of biotechnology in agricultural crop improvement.

2. Potentials of Biotechnology in Crop Improvement

Biotechnology should not be understood as a substitute for traditional tools of crop improvement. But integrating recombinant techniques into conventional breeding programs could substantially enhance the efficiency of agricultural research and development. On the one hand, breeding could be accelerated due to the more targeted transfer of desired genes into the crop. On the other hand, biotechnology could bring forth new crop traits that are not amenable to the conventional approach. Whereas traditional crossbreeding is confined to the exchange of genetic material within a certain crop species, recombinant techniques enable the transfer of valuable genes across species and even across kingdoms. A case in point is *Bt* maize, where a gene of the soil bacterium *Bacillus thuringiensis* (*Bt*) has been incorporated into the plant genome to confer resistance to particular insects. The major transgenic breeding objectives are described in the following [1, 10].

2.1. Potential of Biotechnology on Agronomic Traits

The category of agronomic traits embraces all genetic modifications of plants that help to stabilize or increase the yields in farmers' fields. Since the immediate benefits of such traits accrue at the level of agricultural production, they are often referred to as 'input traits'. Prominent input traits are mechanisms of pest and disease resistance, which are often encoded by only a single gene (monogenic traits). Different transgenic pest and disease resistances have already been commercialized. In assessing the potential value of such traits it has to be considered that global crop losses induced by biotic stress factors reach a level of 25-30% [20].

Biotechnology could substantially reduce these losses without the need for increased pesticide applications. Other desirable agronomic crop traits include enhanced genetic yield potentials and tolerance mechanisms to abiotic stresses, such as drought, coldness and nutrient deficiencies in soils. Since these latter traits are usually determined by multiple genes (polygenic traits), the research is often more complicated. Recent advances in molecular mapping and functional genomics, however, demonstrate that related biotechnology products are also quite realistic in the near to medium-term future. Thus, improved crop varieties could also be tailored to marginal agro-ecological regions, which have been largely neglected by the green revolution [20].

2.2. Potential of Biotechnology on Quality Traits

In contrast to the agronomic traits, which help increase the quantity of agricultural production, quality traits are related to the appearance or the chemical composition of the crop product. Hence, they are often referred to as 'output traits'. Quality traits can include enhanced densities of macro- and micronutrients essential for healthy human diets. If such traits are incorporated into staple food crops they could be beneficial especially for poor population segments that often lack the purchasing power to buy sufficient amounts of higher-value and more nutritious foods [23].

Researchers, for instance, managed to develop transgenic rice varieties with significantly enhanced vitamin A contents, now being used in rice breeding programs [23]. It is estimated that worldwide more than 400 million people suffer from vitamin A deficiency which often leads to irreversible blindness and other deleterious health problems. Promising advances in biotechnological research to improve the micronutrient density in plants has also been reported for a number of other important vitamins and minerals. Although somewhat less related to food security, biotechnology also permits to modify plants in a way that they produce significant amounts of special chemicals, such as vaccines, other pharmaceuticals or biodegradable plastics.

3. Achievements of Biotechnology in Crops

3.1. Achievements of Genetic Engineering in Crop Improvement

Deliberate alteration of the genome of an organism by introduction of one or a few specific foreign genes is referred to as 'genetic engineering' or 'genetic transformation', and the modified organism is described as a 'transformed' or 'transgenic' organism. Genetic engineering plays a significant role in enhancing protein, vitamin A and vitamin E as well as iron and zinc components by gene insertion. Specifically, advances in genetic engineering have made possible the manipulation of crops to increase yield, guaranteeing food supplies for the increasing world population [22].

3.1.1. Bt Crops

Several crops have been genetically engineered to produce their own Bt proteins, making
them resistant to specific groups of insects. The bacterium ***Bacillus thuringiensis*** has been used to produce transgenic plants known as Bt plants. The bacterium produces toxic crystals that kill caterpillar pests when they ingest the toxin. The bacterium itself has been used as an insecticide, sprayed directly onto crops. However, the gene for toxin production has been isolated and inserted into plants such as corn, cotton, soybean, and potato, with the first Bt crops planted in 1996. By 2000 over half of the soybean crop in the USA was planted with Bt-engineered plants, although there have been some problems with pests developing resistance to the Bt toxin [18].

Bt corn is a variant of GM maize that expresses the bacterial Bt toxin, which is poisonous to the European corn borer. However, there are several foods from GM crops that are resistant to herbicides (glyphosate) and/or resistant to insects (using Bt toxin), including crops such as soybean, canola, sweet corn and sugar beet [3]. However, despite the different biotechnological achievements, the consumption of transgenic food is still associated with a lack of knowledge regarding their effects on the environment and human health [5].

3.1.2. Golden Rice

In 1992, the Golden Rice project started. Golden Rice is a variety of *Oryza sativa* designed
to produce beta-carotene, a precursor of vitamin A, in the endosperm, which is the edible part of rice. It was created by Ingo Potrykus of the Institute of Plant Sciences at the Swiss Federal Institute of Technology, working together with Peter Bayer of the University of Freiburg [3]. Golden rice was developed as a fortified food to be used in areas where there is a shortage of dietary vitamin A. A new variety called Golden Rice 2 was announced in 2005. Golden Rice 2 produces up to 23 times more beta-carotene than the original version.

3.1.3. Herbicide Resistance Crop

Herbicide resistance is one area where a lot of effort has been directed. The theory is simple if plants can be made herbicide-resistant, then weeds can be treated with a broad-spectrum herbicide without the crop plant being affected. One of the most common herbicides is glyphosate, which is available commercially as Roundupand Tumbleweed. Glyphosate acts by inhibiting an amino acid biosynthetic enzyme called 5-enolpyruvylshikimate-3-phosphate synthase (EPSP syntheses or EPSPS) [5].

Resistant plants have been produced by either increasing the synthesis of EPSPS by incorporating extra copies of the gene, or by using a bacterial EPSPS gene that is slightly different from the plant version and produces a protein that is resistant to the effects of glyphosate. Monsanto has produced various crop plants, such as soya, that are called Roundup-ready, in that they are resistant to the herbicide. Such plants are now used widely in the USA and some other countries, and herbicide resistance is the most commonly manipulated trait in genetically modified (GM) plants [18].

3.1.4. Drought Tolerance

Selection for drought tolerance is difficult due to a complex genotype and by environment interactions. Recent progress in genomics makes possible a more efficient assessment and enhanced diversity in germplasm collections, introgression of valuable traits from new sources and identification of the genes that control key traits. Marker-assisted selection helps to reduce the environmental impact of breeder selection. Significant advances have been made in the development of in vitro selection methods [21].

The broader use of traits from alien species and the manipulation of heterosis and polyploidy create new perspectives for improving yield potential and adaptation to abiotic stresses. The use of the knowledge generated by these approaches should clarify the functional basis of drought adaptation traits. The integration of these new methods and tools into breeding programs and their potential impact on the development of drought-tolerant germplasm are discussed [21].

Table 1. *Examples of GMOs Resulting from Agricultural Biotechnology.*

Genetically Conferred Trait	Example Organism	Genetic Change
APPROVED COMMERCIAL PRODUCTS		
Herbicide tolerance	Soybean	Glyphosate herbicide (Roundup) tolerance conferred by expression of a glyphosate-tolerant form of the plant enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) isolated from the soil bacterium *Agrobacterium tumefaciens*, strain CP4
Insect resistance	Corn	Resistance to insect pests, specifically the European corn borer, through the expression of the insecticidal protein Cry1Ab from *Bacillus thuringiensis*
Altered fatty acid composition	Canola	High laureate levels achieved by inserting the gene for ACP thioesterase from the California bay tree *Umbellulariacalifornica*
Virus resistance	Plum	Resistance to plum pox virus conferred by insertion of a coat protein (CP) gene from the virus
PRODUCTS STILL IN DEVELOPMENT		
Vitamin enrichment	Rice	Three genes for the manufacture of beta-carotene, a precursor to vitamin A, in the endosperm of the rice prevent its removal (from husks) during milling
Vaccines	tobacco	Hepatitis B virus surface antigen (HBsAg) produced in transgenic tobacco induces an immune response when injected into mice
Oral vaccines	Maize	Fusion protein (F) from Newcastle disease virus (NDV) expressed in corn seeds induces an immune response when fed to chickens
Faster maturation	Coho salmon	A type 1 growth hormone gene injected into fertilized fish eggs results in 6.2% retention of the vector at one year of age, as well as significantly increased the growth rate

Source: [23]

3.2. Achievements of Plant Tissue Culture in Crop Improvement

Tissue culture is the regeneration of plants in the laboratory from disease-free plant parts. This the technique allows for the reproduction of disease-free planting material for crops. Examples of crops produced using tissue culture include citrus, Pineapples, Avocados, Mangoes, Bananas, Coffee, Sugarcane, Apple and Papaya.

Plant tissue culture is an enabling technology from which many novel tools have been developed to assist plant breeders. These tools can be used to increase the speed or efficiency of the breeding process, to improve the accessibility of existing germplasm and to create a new variation for crop improvement. They include micropropagation, anther culture, in vitro selection, embryo rescue, Somaclonal variation, somatic hybridization and transformation [13].

3.2.1. Clonal Propagation

The proven practical record of techniques such as micro-propagation means that methods are quite well advanced and are being exploited for the aims of the development of crops. For instance, meristem culture has an established record of success in the tuber and root crops like cassava, yams, sweet potato, Irish potato and fruit tree crops such as citrus [8].

3.2.2. Micrografting

This technique involves the excision of mature meristem from fruit and forest trees and the grafting of these under aseptic conditions onto seedling rootstocks. The objectives of this method are to obtain disease-free scion materials of fruit trees, e.g. citrus [17] and to obtain rejuvenated shoots from mature trees.

3.2.3. Somaclonal Variability

A Somaclonal variation is a tool that can be used by plant breeders. The main factors that influence the variation generated from tissue culture are (1) the degree of departure from organized growth, (2) the genotype, (3) growth regulators and (4) tissue source. Somaclonal variants generated from callus cultures of sugar cane, tobacco, sorghum, potato, rice, and wheat have provided breeders with new sources of variability to incorporate into conventional breeding programs. Agronomically useful traits such as increased tolerance to physiological stress and pests and diseases have been recovered from such materials [13].

3.2.4. Haploid Plant Production

Relatively short periods of time are all that are needed to generate homozygous breeding lines of tropical cereals if haploid or diploid plants can be regenerated from immature pollen. Conventional pedigree methods of homozygous plant generation take 5- 6 years and longer but in some cases, regeneration of haploid plants has been achieved in less than two years, e.g. for barley, tobacco, and rice. The method, therefore, is saving valuable time and field space [12].

3.2.5. Somatic Hybridization

Protoplast fusion represents one way to create much-needed gene-flow between wild species with stress tolerance features and intolerant cultivated species [7]. Provided regeneration of plants from isolated protoplasts is possible. The plant tissue culture techniques such as seed culture, meristem culture, bud culture, callus culture are also the achievement of biotechnology through plant tissue culture techniques used for crop improvements.

4. Conclusions and Summary

Biotechnology in agriculture has diversified applications, multiple technologies approaches, and a large repertoire of products. The promise of the plant in vitro technologies in three major areas (micropropagation, somatic cell genetics, and generation of transgenic plants). Hybrid seed production in plants is developing rapidly. Improvement of novel biotechnologies that involves gene manipulation, somatic hybridization and mutagenesis have led to the identification of the roles of specific mitochondrial, chloroplast, and nuclear DNA elements in cell growth, fertility, and control of blossom.

Yet biotechnology could contribute to sustainable development in two important respects. First, integrated into existing crop improvement programs biotechnology could increase agricultural productivity beyond what is possible with conventional breeding techniques alone. This would enhance global food availability at affordable prices while promoting environmentally sound production patterns. Second, appropriate biotechnologies could raise the revenues in agricultural production, which is still the dominant source of income and employment for the rural poor in large parts of the world.

Generally, the role of crop biotechnology for food security and poverty reduction should not be overrated. Many problems in low- and middle-income countries are not amenable to technological solutions. Genetically engineered crop varieties that farmers deploy. Transgenic crops, especially those with resistance to biotic and abiotic stress factors, fit well into small-scale farming systems and can easily be integrated without adjusting traditional cropping practices. The comparatively low setup cost for adopting genetically engineered technologies at the farm level also makes this technology useful for semi-subsistence agriculture.

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