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Role of Biotechnology in Agriculture

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Abstract—*Contrary to its name, biotechnology is not a single technology. Rather it is a group of technologies that share two (common) characteristics -- working with living cells and their molecules and having a wide range of practice uses that can improve our lives. Biotechnology can be broadly defined as "using organisms or their products for commercial purposes." As such, (traditional) biotechnology has been practices since the beginning of records history. It has been used to bake bread, brew alcoholic beverages, and breed food crops or domestic animals. But recent developments in molecular biology have given biotechnology new meaning, new prominence, and new potential. It is (modern) biotechnology that has captured the attention of the public. Modern biotechnology can have a dramatic effect on the world economy and society. Modern biotechnology represents unique 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. The consequences of the invention of DNA-based molecular techniques and their application to agriculture have been pervasive. These include widespread commercial applications of agricultural biotechnology in a limited number of countries and global status of agricultural biotechnology. This review examines current genetic engineering techniques allow segments of DNA that code genes for a specific characteristic to be selected and individually recombined in the new organism. The precision and versatility of today's biotechnology enable improvements in food quality and production to take place more rapidly than when using traditional breeding. The biotechnology tools that are important for agricultural biotechnology include conventional plant breeding, tissue culture and micro propagation, molecular breeding or marker assisted selection, genetic engineering and GM crops, molecular diagnostic tools.*

Keywords*: biotechnology, agricultural biotechnology, genetic engineering, transgenic.*

1. INTRODUCTION

For about 10,000 years, farmers have been improving wild plants and animals through the selection and breeding of desirable characteristics. This breeding has resulted in the domesticated plants and animals that are commonly used in crop and livestock agriculture. In the twentieth century, breeding became more sophisticated, as the traits that breeders select for include increased yield, disease and pest resistance, drought resistance and enhanced flavour. Traits are passed from one generation to the next through genes, which are made of DNA. All living things—including the fruits, vegetables and meat that we eat—contain genes that tell cells how to function. Recently, scientists have learned enough to begin to identify and work with the genes (DNA) that are responsible for traits. The consequences of the invention of DNA-based molecular techniques and their application to agriculture have been pervasive, both within the agriculture sector and outside it. Increased food production and profits were probably the primary hoped-for results by scientists who pioneered agricultural biotechnology while widespread public skepticism and even vociferous opposition probably were not anticipated.

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.

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 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.

Current genetic engineering techniques allow segments of DNA that code genes for a specific characteristic to be selected and individually recombined in the new organism. Once the code of the gene that determines the desirable trait is identified, it can be selected and transferred. Similarly, genes that code for unwanted traits can be removed. Through this technology, changes in a desirable variety may be achieved more rapidly than with traditional breeding techniques. The presence of the desired gene controlling the trait can be tested for at any stage of growth, such as in small seedlings in a greenhouse tray. The precision and versatility of today's biotechnology enable improvements in food quality and production to take place more rapidly than when using traditional breeding. The biotechnology tools that are important for agricultural biotechnology include conventional plant breeding, tissue culture and micro propagation, molecular breeding or marker assisted selection, genetic engineering and GM crops, molecular diagnostic tools.

2. APPLICATIONS OF AGRICULTURAL BIOTECHNOLOGY

The primary tools used in agricultural biotechnology are defined below using layman's definitions to serve the purposes of the review

_ ***Genetic engineering*** inserts fragments of DNA into chromosomes of cells and then uses tissue culture to regenerate the cells into a whole organism with a different genetic composition from the original cells. This is also known as rDNA technology; it produces transgenic organisms.

_ ***Tissue culture*** manipulates cells, anthers, pollen grains, or other tissues; so they live for extended periods under laboratory conditions or become whole, living, growing organisms; genetically engineered cells may be converted into genetically engineered organisms through tissue culture.

_***Embryo rescue*** places embryos containing transferred genes into tissue culture to complete their development into whole organisms. Embryo rescue is often used to facilitate "wide crossing" by producing whole plants from embryos that are the result of crossing two plants that would not normally produce offspring.

_***Somatic hybridization*** removes the cell walls of cells from different organisms and induces the direct mixing of DNA from the treated cells, which are then regenerated into whole organisms through tissue culture.

_***Marker-aided genetic analysis*** studies DNA sequences to identify genes, QTLs (quantitative trait loci), and other molecular markers and to associate them with organismal functions, i.e., gene identification.

_***Marker-aided selection*** is the identification and inheritance tracing of previously identified DNA fragments through a series of generations.

_***Genomics*** analyses whole genomes of species together with other biological data about the species to understand what DNA confers what traits in the organisms. Similarly, proteomics analyses the proteins in a tissue to identify the gene expression in that tissue to understand the specific function of proteins encoded by particular genes. Both, along with metabolomics (metabolites) and phenomics (phenotypes), are subcategories of bioinformatics.

3. HOW LONG HAS BIOTECHNOLOGY BEEN USED IN AGRICULTURE AND FOOD PRODUCTION?

The first food product of biotechnology (an enzyme used in cheese production and yeast used for baking) appeared on the market in 1990. Since 1995, farmers have been growing GE crops. In 2013, 7 million farmers in 18 countries—more than 85 % of them resource-poor farmers in the developing world—were planting biotech crops. Almost one third of the global biotech crop area was grown in developing countries.

4. WHAT ARE GENETICALLY ENGINEERED (GE) CROPS?

Genetic Engineering is the introduction of a specific gene into the DNA of a plant to obtain a desired trait. The gene introduced may come not only from another plant species, but also from other organisms. While traditional plant breeding involves crossing related plants, biotechnology is a new tool that enhances the capability of breeders to be more precise.

5. GOALS OF GENETIC ENGINEERING

The goals of genetic engineering are the same as with traditional breeding. They may aim to improve crop performance in the field by conferring pest and disease resistance, herbicide resistance, or tolerance to environmental stresses (such as drought or flooding). They may also aim to develop products with enhanced value, such as improved post-harvest life, nutritional value, or other health benefits.

Insect resistance

In the last few years, several crops have been genetically engineered to produce their own Bt proteins, making them resistant to specific groups of insects. "Bt" is short for *Bacillus thuringiensis*, a soil bacterium that contains a protein that is toxic to a narrow range of insects, but not harmful to animals or humans. Applications of Bt bacteria have been used to control insect pests for many years, before the advent of the current Bt crops made using biotechnology. Varieties of Bt insect-resistant corn and cotton are now in commercial production. Other crops being investigated include cowpeas, sunflower, soybeans, tomatoes, tobacco, walnut, sugar cane, and rice.

Herbicide tolerance

Chemical herbicides are frequently used to control weeds. Weeds growing in the same field with crop plants can significantly reduce crop yields because the weeds compete for soil nutrients, water, and sunlight. Many farmers now control weeds by spraying herbicides directly onto the crop plants. Because these herbicides generally kill only a narrow spectrum of plants (if they didn't, they would kill the crop plants, too), farmers apply mixtures of multiple herbicides to control weeds after the crop has started to grow.

Researchers realized that if a crop plant is genetically engineered to be resistant to a broad-spectrum herbicide, weed management could be simplified and safer chemicals could be used. It is often argued that such GE varieties reduce soil erosion, because they make adoption of soil-conserving practices such as “no-till” easier. Resistance to synthetic herbicides has been genetically engineered into corn, soybeans, cotton, canola, sugar beets, rice, and flax. Some of these varieties are commercialized in several countries. Research is on-going on many other crops. One application of this technology is that herbicide could be coated on seed from an herbicide resistant variety (for example, maize) and while the maize would germinate and thrive, weeds and parasites such as Striga would be killed.

Virus resistance

Many plants are susceptible to diseases caused by viruses, which are often spread by insects (such as aphids) from plant to plant across a field. The spread of viral diseases can be very difficult to control and crop damage can be severe. Insecticides are sometimes applied to control populations of transmitting insects, but often have little impact on the spread of the disease. Often the most effective methods against viral diseases are cultural controls (such as removing diseased plants) or plant varieties bred to be resistant (or tolerant) to the virus, but such strategies may not always be practical or available. Scientists have discovered new genetic engineering methods that provide resistance to viral disease where options were limited before.

Foods with improved nutritional value

Researchers are using biotechnology for the development of foods with improved nutritional value. Genetic modification can be used to produce crops that contain higher amounts of vitamins to improve their nutritional quality. Genetically altered “golden rice,” for example, contains three transplanted genes that allow plants to produce beta-carotene, a compound that is converted to vitamin A within the human body. Vitamin A deficiency—the world’s leading causes of blindness—affects as many as 250 million children. Biotechnology has also been used to alter the content of many oil crops, either to increase the amount of oil or to alter the types of oils they produce. Biotechnology could also be used to upgrade some plant proteins now considered incomplete or of low biological value because they lack one or more of the ‘essential’ amino acids. Examples include maize with improved protein balance and sweet potatoes with increased total protein content. Reducing toxicity of certain foods is also a goal of biotechnology. For example, reduction of the toxic cyanogens in cassava has been shown to be possible and could be produced in the future.

6. HOW DOES GENETIC ENGINEERING DIFFER FROM TRADITIONAL BIOTECHNOLOGY?

In traditional breeding, crosses are made in a relatively uncontrolled manner. The breeder chooses the parents to cross, but at the genetic level, the results are unpredictable. DNA from the parents recombines randomly, and desirable traits such as pest resistance are bundled with undesirable traits, such as lower yield or poor quality. Traditional breeding programs are time-consuming and labour-intensive. A great deal of effort is required to separate undesirable from desirable traits, and this is not always economically practical. For example, plants must be back-crossed again and again over many growing seasons to breed out undesirable characteristics produced by random mixing of genomes.

7. STATUS OF GLOBAL AGRICULTURAL BIOTECHNOLOGY

1. While the United States is the leader in both research and commercial applications, biotechnology research is also conducted by many European and Asian research institutions and industry, as well as in more advanced developing countries and by the International Agricultural Research Centres (IARCs).

2. The private sector dominates agricultural biotechnology, funding over 50% of the research and development in the United States. The strength of the private over the public sector introduces important issues that must be addressed when considering the needs of developing countries.

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