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Role of Biotechnology in Agriculture

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Introduction

The broad concept of "biotech" or "biotechnology" encompasses a wide range of procedures for the modification of living organisms for human purposes, including the domestication of animals, the cultivation of plants, and "improvements" to them through breeding programs that use artificial selection and hybridization. Biotechnology in general, includes a wide variety of innovations and applications for the development of useful living goods and services. Agricultural biotechnology is an area of agricultural science that uses methods of cell and molecular biology to enhance genetic composition and agronomic management of crop plants. Green biotechnology is a form of biotechnology applied to agricultural processes. Green biotechnology is expected to produce a more environment friendly solution than traditional industrial agriculture. An example of this is the engineering of a pesticide-expressing plant, eliminating the need for external application of pesticides for example Bt corn. It is commonly seen as the next phase of the green revolution, and a platform to eradicate worlds' hunger by using technologies that enable the production of biotic and abiotic stress tolerant plants. Many crops have been engineered to be resistant to various plant diseases and insect pests, which can make control of pests more efficient and effective, and/or reduce the use of synthetic pesticides. These crop production options can help countries keep pace with food demands while reducing production costs.

Farmers, manufacturers and customers have benefited from the use of biotechnology in agriculture. Biotechnology has helped to make pest control and weed management safer and simpler while shielding crops from disease. For example, genetically modified insect-resistant cotton has contributed to a major reduction in the use of permanent, synthetic pesticides that can contaminate groundwater and the environment. In terms of improved weed control, herbicide-tolerant soybeans, cotton and corn make the use of low-risk herbicides that break down more easily in soil and are non-toxic to wildlife and humans. Herbicide-tolerant crops are particularly compatible with no-tillage or reduced tillage farming systems which help to protect the soil from erosion. Agricultural biotechnology has been used to protect crops against destructive diseases. For example, the papaya ringspot virus threatened to destroy the Hawaiian papaya industry before disease-resistant papaya was developed through genetic engineering. This saved the papaya industry in the United States. Research on potatoes, squash, tomatoes, and other crops continues in a similar way to provide resistance to viral diseases that are otherwise very difficult to control. Biotech crops can make farming more profitable by increasing the quality of crops and, in some cases, increase yields. The use of some of these crops may simplify the work and improve the safety of farmers. This allows farmers to spend less time managing their crops, and more time on other profitable activities. Biotech crops may provide enhanced quality traits, such as increased levels of beta-carotene in rice, to help reduce vitamin A deficiencies and improve oil composition in canola, soya and corn.

Applications of Biotechnology in Agriculture

Genetically modified crops: GM crops are plants used in agriculture, in which DNA has been modified using genetic manipulation techniques. The main aim is to introduce a new trait that does not occur naturally in the species. Genetically modified foods are foods produced from organisms that have undergone specific changes in their DNA with genetic engineering methods. GM crops can deliver a range of ecological advantages, if not overused. Opponents have, however, objected to GM crops *per se* on many grounds, including environmental issues, whether food derived from GM crops is healthy, whether GM crops are required to fulfill world food needs, and economic concerns posed by the fact that such species are subject to intellectual property laws. GMO's can be used in the following ways:

- They are resistant to various abiotic stresses such as cold, drought and heat etc.
- They are tolerant to pests
- They help to reduce post-harvest losses
- Genetically modified plants have enhanced nutritional value. An example is Vitamin A enriched rice.

So far, most genetic food modifications have concentrated mainly on high-demand cash

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crops by farmers including soybean, corn, canola, and cotton seed oil. They have been developed for pathogen and herbicide resistance as well as for improved nutrient profiles. Some examples of genetically modified plants are:

1. **Flavr Savr Tomato:** Commercial sales of genetically modified foods began in 1994, when Calagen first commercialized its Flavr Savr late ripening tomatoes. Molecular genetic technology was used to slow down the process of softening and rotting caused by fungal infections, which led to increased shelf life of the GM tomatoes. Additional genetic modification improved the flavor of this tomato. The Flavr Savr tomato did not successfully stay in the market because of problems of maintaining and shipping.

2. **Golden Rice:** Agricultural biotechnology offers various nutritional benefits. One example of this is 'Golden rice' which contain beta carotene, a vital source of vitamin A for the body. The name 'Golden rice' comes from the color of the transgenic grain made from three genes out of which two are from daffodils and one from the bacterium. These three genes were cloned to obtain 'Golden rice'.

3. **Genetically engineered Herbicide-tolerant (HT) crops:** A gene isolated from gram positive soil bacterium *Agrobacterium tumefaciens*, is used in genetically engineered HT crops. It makes the recipient plant tolerant to the broad-spectrum herbicide glyphosate. HT crops can reduce the cost of production and help in managing weeds. The HT crop has been developed under name of Roundup Ready (RR). RR soya beans were released for commercial cultivation in 1996 (James, 2002). The yield of RR soya bean is similar to traditional soya beans, but reduces cultivation costs (Fernandez-Cornejo *et al.*, 2000).

4. **Resistance to drought:** Although conventional breeding for drought tolerance continues to have impact, it is time-consuming and is restricted by the accessibility of suitable genes for breeding. Some examples of conventional breeding programs for drought tolerance are the development of rice, wheat and Indian mustard varieties tolerant to salt and to alkali soils by the Central Soil Salinity Research Institute in Karnal, India (CSSRI., 2001); the development of maize hybrids with increased drought tolerance (Bruce *et al.*, 2002); efforts to incorporate salt tolerance to wheat from wild related species (Colmer *et al.* 2006); and the incorporation of drought tolerance as a selection trait in the generation of new maize and wheat germplasm by the International Maize and Wheat Improvement Center (Ribaut *et*

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al 2004). Through genetic engineering, on the other hand, the production of tolerant crops involves identifying main genetic determinants underlying stress tolerance in plants, and incorporating these genes into crops. Drought causes a wide variety of physiological responses in plants and influences the function of a large number of genes. Work on gene expression has identified several hundred genes that are either triggered or repressed during drought (Sahi *et. al.*, 2006). Gene responsible for drought resistance have been identified, isolated and transferred to crop plants using the techniques of gene transformation. Mostly two approaches i.e. targeted and short gun approach aid genetic engineering to obtain transgenic plants conferring drought resistance (MacKenzie and McLean, 2002).

5. ABA independent gene regulation to drought stress: The DREB1 and DREB2 transcription factors are essential for ABA-independent drought-tolerant pathways that induce the expression of stress response genes. Over-expression of the native form of DREB1 and the constitutively active form of DREB2 enhances the resistance of transgenic Arabidopsis plants to drought, high salinity and cold. While these genes were initially discovered in Arabidopsis plants, their presence and role in stress tolerance has been documented in many other important crops, such as rice, tomatoes, barley, canola, maize, soybean, rye, wheat and maize, suggesting that this is a conserved, universal stress defense mechanism in plants (Shinozaki and Yamaguchi-Shinozaki, 2007).

6. Resistance to insects: The Bt gene was isolated from the common soil bacterium *Bacillus thuringiensis* and transferred to cotton, which results in the production of a specific type of protein in cotton. This protein is lethal to certain insects such as pink bollworm (*Pectinophora gossypiella*) and cotton boll worm (*Helicoverpa zea*), and is partially efficient in controlling tobacco bud worm (*Helio thisvirescens*) and fall armyworm (*Spodoptera frugiperda)* (James, 2002). Using gene transfer technique, the Bt gene (Cry I protein from *Bacillus thuringiensis*) has been transferred to number of crop plants such as rice, cotton, tomato, potato, etc. and insect resistant plants (Bt. crops) have been developed.

7. Nematode resistant plants: Several nematodes live as parasites on multiple hosts such as plants, animals and humans. A specific nematode *Meloidegyne incognitia*, infects the roots of tobacco plants which causes a decrease in crop yield. In order to prevent this infestation, a novel strategy based on RNA interference (RNAi) has been adopted.

8. **Micropropagation**: Micropropagation is one of the methods used in tissue culture to rapidly increase the growing stock of required plant material. The propagated plants are usually disease-resistant. This is an innovative technique for vegetative propagation. To produce a large number of the same plants with the same genetic makeup, micropropagation can be used commercially for asexual propagation from small explants. Within a short period, a large number of plants can be produced and can also be preserved within small spaces, protecting some of the endangered species and germplasms. One of the best examples of this technique is disease free Banana. Micropropagation is a way to regenerate disease-free banana plantlets from healthy tissues. It has all the benefits of being a fairly inexpensive and easy-to-use process. Other examples of crops produced using tissue culture are avocados, pineapple, citrus, coffee and papaya.

The applications of agricultural biotechnology are useful in sustained food production. It offers a range of resources for enhancing our understanding and managing the genetic resources for food and agriculture. Modern biotechnology exhibits unique applications of science that can be used for the betterment of society through development of crops with enhanced nutritional quality, resistance to pests and diseases, and low cost of production. Biotechnology, in the context of genetic modification, is an aspect of science that, if used with caution and ethics, has the potential to offer substantial benefits (Wieczorek, 2003).

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