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Use of Plant Biotechnology in Agriculture

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Introduction

Producing enough food, feed, fiber, and biofuel to meet society's needs has been the goal of agriculture for thousands of years. Sustainable agriculture attempts to fulfill these same basic societal demands with an emphasis on preserving environmental quality, decreasing agricultural inputs, reducing environmental effects, and sustaining economic viability.

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. 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. Additionally, genetic and molecular tools are being used to produce transgenic (also referred to as genetically modified (GM)) crops, which are central to the field of modern agricultural biotechnology. Genetically modified crops possess one or more useful traits, such as, herbicide tolerance, insect resistance, abiotic stress tolerance, disease resistance, and nutritional improvement. To date, nearly 525 different transgenic events in 32 crops have been approved for cultivation in different parts of the world.

Genetic engineering:

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. Genetically engineered varieties of maize (corn), cotton, canola, and soybean were widely planted in North America and Asia while there was minimal use of such varieties in Europe and Africa.

- ***Increased crop productivity:*** At present, only a few first-generation technologies have been commercialized. The dominant technology is herbicide tolerance (HT) in soybeans, which made up 53% of the global GM crop area in 2008. GM maize is the second-most dominant crop and covered 30% of the global GM area and 24% of total maize production in 2008 (James 2008).
- ***Enhanced crop protection:*** Cotton was the first commercially successful crop in which cry genes were incorporated to provide resistance against lepidopteron insect pest (Perlak *et al*. 1991). The dominant technology is HT in soybeans, which made up 53% of the global GM crop area in 2008. HT crops are tolerant to certain broad-spectrum herbicides such as glyphosate and glufosinate, which are more effective, less toxic, and usually cheaper than selective herbicides (Trigo and Cap 2006).
- ***Improvements in food processing:*** In 1994, transgenic tomato, 'Flavr Savr' with the property of longer shelf life or delayed ripening developed by Calgene (Monsanto), was approved by Food and Drug Administration (FDA) for sale in the USA.
- ***Improved nutritional value:*** To combat vitamin A defciency, transgenic rice enriched with provitamin A in its endosperm by engineering pathway for β-carotene biosynthesis was developed (Ye *et al*. 2000). In 2017–18, one event of this provitamin A biofortifed rice line GR2E was approved for use as food in Australia, New Zealand, Canada and the United States under the Golden Rice trade name (ISAAA database 2019).

Tissue culture:

It 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. Endangered, threatened and rare species have successfully been grown and conserved by micropropagation because of high coefficient of multiplication and small demands on number of initial plants and space. Meristem tip culture of banana plants devoid from banana bunchy top virus (BBTV) and brome mosaic virus (BMV) were produced (El-Dougdoug and El-Shamy, 2011).

Embryo rescue:

It 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. Intra-varietal hybrids of an economically important energy plant "*Jatropha*" have been produced successfully with the specific objective of mass multiplication (Mohan *et al.* 2011).

Somatic hybridization:

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. A successful protocol has been developed for regeneration of cotton cultivars with resistance to *Fusarium* and *Verticillium* wilts (Han *et al.* 2009).

Marker-aided genetic analysis:

It 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. Genetic maps with a high density of markers have been used to locate discrete Mendelian components of quantitatively inherited traits in a few crop plants.

Genomics analyzes:

Genomics analyzes whole genomes of species together with other biological data about the species to understand what DNA confers what traits in the organisms. Similarily, 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.

Considering the ever-increasing human population, shrinking arable land area and the rapid pace of climate change, there is a need to develop high-yielding crop varieties which are nutritionally enriched and tolerant to various environmental and biotic stresses. Transgenic technology has contributed towards development of crop varieties with enhanced yield, resistance to biotic and abiotic stresses, and enhanced food quality. Further, estimates also suggest that adoption of the transgenic technology has helped in reducing the use of pesticides and insecticides, decreasing environmental footprint and increasing farmer income.

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