

Review Article

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Application of Plant Biotechnology in Improvement of Vegetable Breeding

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ABSTRACT

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The advent of modern biotechnology furnishes a new track of breeding vegetable crops. The term biotechnology defined as a group of technologies that employ biological entities or processes to create new and useful products and processes. It is being used to address problems in areas of vegetable production and processing. It was estimated that 2.6 million deaths worldwide and 31 % of cardiovascular diseases may be attributed to inadequate consumption of fruit and vegetables according to WHO reports, 2002. Vegetables thus play vital role in ensuring good health as it is rich source of vitamins, minerals, antioxidants and dietary fibres. Plant biotechnology has been used to raise and stabilize yields of vegetables; to improve resistance to pests, diseases and abiotic stresses such as drought and cold; and to enhance the nutritional content of foods. In this paper, we describe recent approaches, applications, advantages, and problems faced during the application of modern biotechnology in vegetable breeding research. Plant biotechnology has successfully revolutionised the field of biology and molecular breeding, which is accompanied by enhanced productivity and quality of vegetable crops.

Introduction

The advent of modern biotechnology furnishes a new track of breeding vegetable crops. The term biotechnology defined as a group of technologies that employ biological entities or processes to create new and useful products and processes. It is gaining importance in breeding of vegetable plants to accomplish new varieties with high and stable yield, good quality, as well as pest and stress resistance. It has been suggested that the history of plant biotechnology could be traced

back to the cell theory of Matthias Jakob Schleiden (1838) [1], Theodor Schwann (1839) [2] and Virchow (1858)[3] and the discovery of genetic transformation in bacteria by Frederick Griffith, respectively [4]. Early records of biotechnology process such as the fermentation and breeding practices which were inventions of the ancient Egyptians and other products like brew beer by the Sumerians; moldy soybean curds which was used as an antibiotic to treat boils by Chinese; practice of crop rotation to maximize soil fertility; use of powdered

chrysanthemum an insecticide in China etc. However, the era of plant biotechnology is known to begin in the early 1980s with the near stone reports of developing transgenic plants using *Agrobacterium tumefaciens* [5, 6, 7 and 8]. The commercialization of transgenic crops revealed the successful integration of biotechnology into plant breeding and crop improvement programs by 1996 [9].

It was estimated that 2.6 million deaths worldwide and 31 % of cardiovascular diseases may be attributed to inadequate consumption of fruit and vegetables according to WHO reports, 2002[10]. Vegetables play an important role in human nutrition, being mostly low in fat and carbohydrates, but rich in vitamins, minerals, antioxidants and dietary fibres. By using conventional breeding several high yielding hybrid cultivars of different vegetable crops have been developed.

But, it require many generations to get the desired combination of traits, and long-time lags restrict its further prospects, especially for perennial crops such as trees and some species of livestock. Such kind of selection based on the phenotype render a slow, demanding process and also expensive in terms of both time and money. Under such circumstances modern biotechnology proved an efficient tool in supplementing the conventional breeding methods of research and subsequently resulted in quantum jump in the improvement of productivity and nutritional quality of vegetable crops.

Biotechnology is interdisciplinary field which is related to many facets of lives, particularly with global warming, genetically modified drugs, food and energy production. It has been used to develop low-cost disease-free planting materials for crops such as cassava, banana and potato through meristem culture and long-term conservation of genetic

resources through cryopreservation. Plant biotechnology not only accelerated the vegetable breeding programme but also extended the range of traits that can be addressed. By using biotechnological approaches, limitations of conventional breeding such as problem of linkage drag, sexual barrier in wide crosses, anti-nutritional factor etc. can be overcome efficiently and effectively. Recent developments in molecular biology such as in-vitro mutagenesis, genetic engineering (Cisgenesis, transgenic and intragenesis), DNA sequencing, cloning, molecular marker etc. foster new meaning, new dimension, and new potential to old biotechnology. It also provided new perspectives of microbial intervention in agricultural practices, such as bio-fertilizers, bio-control agents, and various microbiological products used in modern agriculture [11]. Thus, modern biotechnology approaches can have a dramatic effect on the improvement of vegetable crops.

Biotechnological approaches

Various biotechnological approaches have been utilized to ameliorate vegetable quality and quantity. Scientists are successful in isolating target gene of interest, its transfer and integration into the host species based on the knowledge of DNA. Plant biotechnology enables amelioration that is not possible with traditional crossing of related species alone. Such approaches have been concisely discussed below.

Genetic engineering

Modern Genetic engineering has the potential to ameliorate quality, productivity and values to vegetable crops. It involves the modification of genetic material of the host plant by introducing new genes for improved agronomic performance and/or enhanced nutrition to provide GM crops which are

under commercial cultivation in many countries [12]. Genetic engineering has also helped immensely in creation of vegetable crops with various beneficial and development traits like flavours and aromas, sizes, harvest durability, colours, tastes, resistance etc.

Molecular markers

Molecular markers directly reveal the polymorphism at the level of DNA and utilized in creation of high-resolution genetic maps and genetic linkage between markers and important crop traits have been exploited for improvement of vegetable breeding [13, 14].

Such molecular marker technique have been utilized for identification for vegetable varieties or cultivars such as in tomato [15], potato [16], onion, garlic, and related species [17] etc. Various molecular markers such as RFLP, RAPD, AFLP, SSR, ESTs, SNPs etc. are used for development of saturated genetic maps; DNA fingerprinting; phylogenetic and evolutionary studies; heterotic breeding; gene tagging and marker assisted selection (MAS).

Cryopreservation

Application of biotechnological processes has a promising role in conservation of germplasm. Cryopreservation is one of the biotechnological tool which involves storage of germplasm at an ultralow temperature, typically that of liquid nitrogen (-196°C). It provides the prospect of storage for indefinite periods with minimal risk. Schemske *et al.*, (1994) reported that the cryopreservation, tissue, organ culture, micro-propagation techniques, germplasm banking, gene banking, applied advanced research have been used to introduce new genetic modification in the existing population, reinforcement of existing population and reintroduction into the wild controlled environments [18].

Tissue culture

Tissue culture refers to the regeneration of plants in the *in-vitro* condition from disease-free plant parts. This technique allows production of clones of a plant in a method known as micro-propagation. Examples of crops produced using tissue culture include citrus, pineapples, avocados, mangoes, bananas, coffee and papaya.

In-vitro mutagenesis

Genetic variability of vegetables could be increased by mutation. Mutations can occur spontaneously in the nature or induced artificially by using either chemical or physical mutagens which leads to sudden heritable change in the genotype of the plant.

Induced mutations have been used mainly to improve particular characters such as earliness, semi-dwarfness, lodging resistance, disease resistance, higher yield and better quality in well-adapted local varieties or to generate variation difficult to be found in germplasm collections. Induced mutagenesis foster easier and rapid identification of location of genes on the chromosomes, study of gene structure, expression and regulation, and exploration of genomes.

Double haploids

It involves techniques like anther and microspore cultures, wide hybridisation, ovary and ovule cultures that have been utilised in a range of economically important vegetable crop species. production of doubled haploids (DHs) is also dependent on totipotency of plants, i.e. whole plant arising from the doubling of chromosome number of gametic cells, pollens and egg cells, prior to their regeneration [19, 20]. By using this technique, homozygous individuals could be produced quite routinely [21].

Table.1 Application of various biotechnology in improving relevant traits in vegetables

Biotechnological approach	Crops	Trait of interest	Reference
Genetic engineering	Potato	Potato tuber moth resistant gene <i>CryIAb</i>	Kumar <i>et al.</i> , 2010 [22]
	Lettuce	Salt resistance	Park <i>et al.</i> , 2005 [23]
	Flavr Savr tomato	suppression of the tomato <i>polygalacturonase (PG)</i> gene,	Sheehy <i>et al.</i> , 1988 [24]
Molecular marker	Tomato	More than 40 genes that confer resistance to major classes of tomato pathogens have been mapped, cloned, and/or sequenced	Grube <i>et al.</i> , 2000 [25]
		Resistant to <i>Meloidogyne incognita</i>	Williamson <i>et al.</i> , 1994 [26]
		tomato mosaic virus resistance	Sobir <i>et al.</i> , 2000 [27]
In-vitro mutagenesis	Potato	Salt resistant	Ochattet <i>et al.</i> , 1998 [28]
Tissue culture	Tomato	Fusarium R, variety DNAP-17 High solid contents var DNAP9	Evans, 1989 [29] Evans, 1989 [29]
	<i>Brassica juncea</i>	High yield, shattering resistant, cv released Pusa Jai Kisan	Katiyar and Chopra, 1995 [30]
	<i>Capsicum</i>	yellow fruit, cv Bell sweet	Morrison <i>et al.</i> , 1989 [31]
		early maturing and high yielding, cv A-D4'	Xu and Chen, 1995 [32]
	Sweet potato	cultivar Scarlet	Moyer and Collins, 1983 [33]
	Tobacco	Atrazine, amitrole, paraquat resistant	Jain <i>et al.</i> , 1998 [34]
	<i>Brassica</i>	Atrazine, phenmedipham resistance	Jain <i>et al.</i> , 1998 [34]
	Tomato	<i>Clavibactermichiganense</i>	Sotirova <i>et al.</i> , 1999; [35]
	Potato	<i>Fusarium solani</i> resistance	Jain <i>et al.</i> , 1998 [34]
		<i>F. oxysporum</i> , <i>Phytophthorainfestans</i> , <i>Alternaria solani</i> , potato leaf roll luteo virus	Cristinzeo&Testa, 1999 [36]
	<i>Brassica</i>	Marsh grass salt tolerance	Kirti <i>et al.</i> , 1991 [37]; Jain <i>et al.</i> , 1990 [34]; Seliskar& Gallagher, 2000[38]
	Tobacco, tomato	Salt tolerance	Remotti, 1998 [39] Boscherini <i>et al.</i> , 1999 [40]

Application of biotechnology in improving relevant traits in vegetable

Several traits have been incorporated to relevant crops by biotechnological approaches. These species include potato,

tomato, *Brassica* spp., sweet potato, cassava etc.

In 1990, the first food product of biotechnology (an enzyme used in cheese production and yeast used for baking) was

made available in the market. Almost one third of the global biotech crop area was grown in developing countries. Some examples reported in the literature are described below (Table 1).

Merits of plant biotechnology in improvement of vegetable breeding

- Safe to use.
- The agriculture advancements resulted in sustainable improvements in agronomic traits of crops such as disease resistance and drought tolerance. In addition to this, plants can now be utilized for biofuel production, phytoremediation, the amelioration of nutritional values in edible plants, the identification of compounds for medicinal purposes in plants and the use of plants as therapeutic protein production platforms such as hirudin (anti-thrombin protein).
- The diversification of plant breeding has resulted in great abundance of new patents issued in these fields and, as many of these inventions approach commercial realization, the subsequent increase in agriculturally-based industries [41].
- Modern agriculture practices furnish large production at the affordable price thus help in ensuring food security.
- Study of gene expression become feasible using novel technologies, such as microarrays and DNA chips [42].

Limitations

- Foreign genes are reported to alter the nutritional value of foods in unpredicted manner.
- Many genetically engineered foods are known to be derived from microorganisms, whose allergenic potential are either

unknown or untested. So there is chance of transfer of allergen properties to GM crops.

- There is possibility of emergence of new super weeds due to cross pollination of GM crops (genetically modified crops) having herbicide and insect resistance with wild species.
- Commercialization of transgenic crops may pose a threat to genetic diversity of crops already endangered by current agricultural practices that favour the worldwide adoption of a few crop varieties.
- Some critics of genetic modification claim that patenting allows inventor to have monopoly control of genetically modified plants or animals.
- Organic farmers fear that one day GM foods would be difficult to be distinguished from non-GM crops as it lacks labelling.

In conclusion, the above review emphasizes that plant biotechnology has revolutionised the field of biology and molecular breeding, which is accompanied by increased productivity and quality of vegetable crops. Such interdisciplinary science requires knowledge of the genomics, transcriptomics and proteomics, a solid foundation in statistical software to estimate genetic effects, strong background in plant biology, experience with both the laboratory methods of molecular biology/functional genomics and field-based breeding practices, and the ability to manage large datasets with diverse data types. To ensure continuous rapid growth of plant biotechnology, plant biotechnologists are required to translate this knowledge into pragmatic applications, especially those that directly benefit the consumers.

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