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Vegetable improvement in India: A review

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Abstract
Vegetables, known for their abundant vitamins, minerals, and antioxidants, are widely recognized as protective foods. Following China, India has emerged as the second-largest global producer of vegetables, thanks to a systematic initiative launched in the 1970s to enhance vegetable output in the country. While conventional breeding methods have yielded diverse public domain varieties with unique characteristics, the focus has shifted towards an integrated approach to vegetable improvement, incorporating various biotechnological tools for genetic enhancement. Traditional breeding methods, though effective, involve a slow and uncontrolled process of genetic improvement that requires multiple generations to achieve desired traits. In contrast, biotechnological methods offer the advantage of introducing individual genes without any undesirable side effects. Although biotechnological techniques have their limitations, the current development demands a multidisciplinary and coordinated strategy that combines conventional and nonconventional methodologies to meet the growing needs.

Keywords: Vegetables, protective food, vitamins, minerals, antioxidants, vegetable output, genetic improvement, desired traits and biotechnological method

Introduction
Vegetables are considered essential for a balanced diet due to their rich content of vitamins, minerals, dietary fiber, and phytochemicals. Their abundance of these nutrients makes them a vital component of a healthy eating regimen (Dias, 2013) [5]. Vegetables are significant in Indian agriculture when addressing food and nutritional security. They are sometimes referred to as "protected food" because of their ability to stave against degenerative illnesses. According to Rahal *et al*. (2014) [31], vegetables are the century's most nutritionally beneficial food. Many different bioactive substances, including vitamins, anthocyanins, flavonoids, carotenoids, and polyphenols, may be found in almost all vegetables. Due to their antioxidant properties, all of these substances are capable of preventing and reducing illness. In accordance with the most recent data, 168.30 million tonnes of vegetables are produced on 9.5 million hectares of land. India is the world's top vegetable producer of okra and comes in second place for its output of potatoes, onions, cauliflower, brinjal, and cabbage. Vegetable crop development has, until recently, primarily been limited to traditional breeding methods, which rely on the interspecific sexual hybridization of plants with desired heritable traits as well as on naturally occurring or experimentally generated random mutations. Re-assorting, which was made possible by advancing breeding procedures through randomly generated modifications, and biochemical engineering have both been used to create whole new possibilities and improvements (Miflin, 2000) [24]. In order to enhance crops in the future, it will be hopeful to combine conventional breeding techniques with biotechnology tools (Dias, 2012) [7]. The current assessment is based on different accomplishments accomplished recently through traditional breeding methods and improvements made to vegetables in India using biotechnological technologies to provide food and nutritional security. Breeding methods and improvements made to vegetables in India using biotechnological technologies to provide food and nutritional security.

Need for improvement
Vegetable quality in India must be improved for a number of reasons
- **Food Security:** Vegetables are an important part of a balanced diet since they include important nutrients, vitamins, and minerals. Vegetable consumption is rising in India as a result of the country's expanding population and urbanization.

The increased demand for vegetables may be met and the population's food security can be ensured by improving vegetable variety.

- **Nutritional Enhancement:** Vegetable development initiatives may concentrate on creating cultivars with improved nutritional value. This involves boosting the number of vitamins, iron, and other crucial minerals in vegetables to treat the micronutrient deficits that are common in some parts of India. Such advancements can considerably help fight hunger and boost general health.
- **Yield Enhancement:** To fulfil the rising demand and enhance farmer livelihoods, it is essential to develop vegetable varieties for higher yields. Increased production and profitability for farmers can be attained with the aid of high-yielding cultivars with enhanced tolerance to pests, diseases, and abiotic challenges. Utilizing land, water, and other resources more effectively might result from increased production potential.
- **Quality Enhancement:** Vegetable types that have been improved may have qualities that make them of higher quality, such as flavour, texture, colour, and shelf life. Both the home market and the export market depend on this. Enhancing customer happiness, boosting market competitiveness, and creating chances for value addition in the vegetable industry may all be achieved by creating varieties with higher quality traits.
- **Pest and Disease Resistance:** A variety of pests and diseases can affect vegetable crops, resulting in considerable output losses. The creation of cultivars with improved resistance to diseases and pests that are common might be given priority in vegetable improvement initiatives. This decreases production costs, lessens the need for chemical pesticides, and encourages ecologically friendly and sustainable agricultural methods.
- **Adaptation to Local Agroecological circumstances:** India is home to several agroecological areas with various soil types, insect pressures, and climate circumstances. Vegetable development initiatives might concentrate on creating varieties that are peculiar to a certain location and are suited to the environment there, assuring maximum performance and yield. Locally tailored variety can also support gastronomic customs, regional food preferences, and ecological farming methods.

Major contributions of conventional vegetable breeding during recent past

The development of off-season varieties of radish, tomato, onion, cabbage, and carrot during the last several decades has allowed farmers to cultivate these veggies all year round. A tropical parthenocarpic gynoecious cucumber line (PKG-1 series) was created on a Poona Khira foundation. Parthenocarpic gynoecious Pusa Seedless cucumber-6 first exceptionally early cultivar, which is ideal for protected situations, has just been produced. Customers enjoy seedless watermelons more since there are no seeds to spit out. Using triploid hybrids is the traditional method for producing seedless watermelons. Pusa Bedana, the first seedless watermelon, was created by crossing Pusa Rasal, the male parent, with Tetra-2, the female parent, four times. Other seedless watermelon varieties that have recently been developed in India include Arka Madhura, which can be grown year-round under protected conditions, Swarna, and Shonima, which were produced by mating a stable tetraploid watermelon line called "KAU-CL-TETRA-1" (4X) with diploid males (2X), specifically CL-4 (red fleshed) and CL-5 (yellow fleshed) (ICAR 2015) [16]. The most common method of producing hybrid seeds before was hand emasculation and hand pollination, but this method is uneconomical in crops where only a small number of seed is produced with each hand pollination. As a result, the cost of hybrid seed can be reduced if mechanisms are available that can be used in real-world situations to prevent selfing and increase out crossing in the field of hybrid seed production (Kumar and Singh, 2004) [20]. Natural pigments found in plant tissue, such as anthocyanins, betalains, carotenoids, and chlorophyll, are referred to as edible colors. These pigments are used increasingly commonly as a source for nutraceuticals to treat a variety of human diseases since they have key metabolic roles in plants (Grotewold, 2006) [11]. Work is being done in India to generate new types of these bioactive substances and edible colors as a natural means of lowering the risk of many chronic illnesses. Nutraceuticals and edible colors can be improved through a variety of breeding techniques, including back crosses, pedigrees, mutation breeding, polyploidy breeding, and the creation of F1 hybrids. According to Moon *et al*. (2002) [25], the beta carotene content of F1 hybrid muskmelon has doubled. Since a long time ago, research has been conducted in India to create biotic stress resistance varieties since it was found that these types of plants were more suitable for producing crops in a sustainable manner. Both Singh and Chaubey (2013) [32] and Meena and Meena (2014) [23] have provided lists of the several variants that have been created. The highest level of development in tomato is multiple resistance to tomato leaf curl virus, bacterial wilt, and early blight. A model of multiple resistance breeding is the tomato cultivar known as Arka Rakshak.

Transgenic or genetically modified crop

According to Anonymous (2015) [1-2], India is the fourth-largest country in the world in terms of the area completely devoted to bt cotton, after the United States, Brazil, and Argentina. In the last two years, transgenic rice, cotton, maize (corn), mustard, brinjal, and chickpea have all been tested in field trials, and there are now eight states participating (Kumar, 2015) [19]. PjVP1, a new gene cloned from the hardy plant *Prosopis juliflora*, has been used to create transgenic tomato plants. Under drought and salt stress, the chosen transgenic tomato line produced more fruit than the control, demonstrating improved drought and salinity tolerance. According to the Annual Report IIVR, 2012-13, a high level of fruit and shoot borer was seen on brinjal (*Solanum melongena*) cv. Kashi Taru plants. Because the AMA1 gene is expressed in ProTato, a transgenic potato line, there is a 48% increase in total protein content compared to non-transformed potatoes (Chakraborty *et al*., 2010) [4].

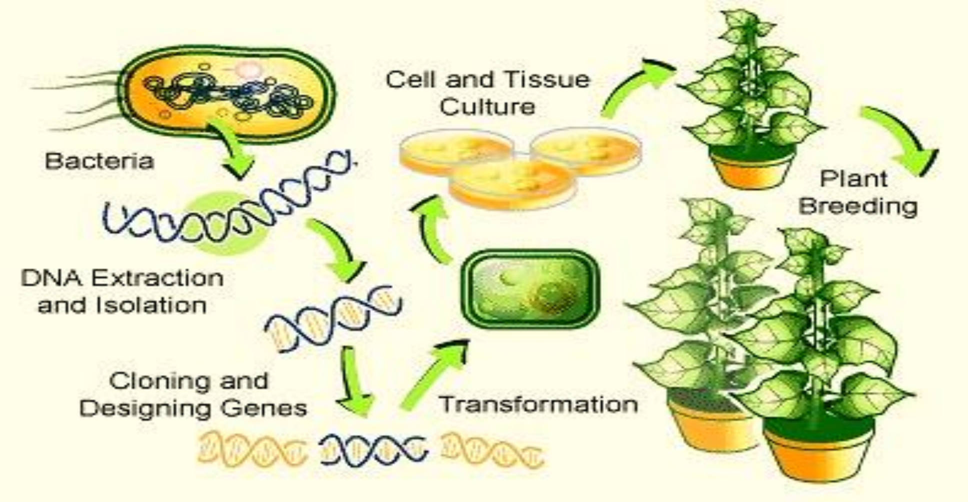

Fig 1: Genetically modified crop

Molecular aided breeding to accelerate the vegetable improvement program

The brief DNA sequences that may be easily tracked and recognized are known as molecular markers or DNA markers. The potential use of molecular markers in vegetable crops has been examined by Ansari (2015) [3]. According to Foolad and Sharma (2005) [9], marker aided selection refers to the selection of a characteristic based on genetics rather than phenotype. Through the use of markers, breeding cycles may be made more efficient and selection can occur more quickly (Holland, 2015) [14]. Through the RAPD methodology, the male sterility and fertility restorer genes in chilli have been identified (Kumar *et al*., 2002) [21]. For the first time in the long-day onion population of India, a DNA marker for male sterility and hybrid development has been developed and identified, and we can now use the identified marker in the future for hybrid development as well as the transfer of male sterility to other onion lines or genotypes through marker-assisted selections (Saini *et al*., 2015) [28]. To generate tomato hybrids resistant to tomato leaf curl, the Ty2 and Ty3 genes have been inserted into the plant via marker-assisted selection (Prasanna *et al*., 2015) [27].

Table 1: Sequenced Genome of Vegetable Crops

S. No.	Crop	Haploid chromosome number(x)	Estimated genome size (Mb)	References
1	Cucumber	7	367.00	Huang *et al*., 2009 [15]
2	Musk melon	12	450.00	Gonzalez *et al*., 2010 [10]
3	Potato	12	844.00	The potato genome sequencing consortium 2011
4	Chinese cabbage	10	529.00	The Brassica rapa genome Sequencing project consortium 2011
5	Tomato	12	900.00	The tomato genome consortium 2012
6	Watermelon	11	425.00	Gau *et al*., 2013 [12]
7	Brinjal	12	1126.00	Hirakawa *et al*., 2014 [13]
8	French bean	11	587.00	Schmutz *et al*., 2014 [29]
9	Chilli	12	3480.00	Kim *et al*., 2014 [18]
10	Cabbage	9	630.00	Liu *et al*., 2014 [21]
11	Pumpkin	20	271.4	Zhang *et al*., 2015 [30]
12	Carrot	18	473	Iorizzo *et al*., 2016 [17]

Tissue culture

Through meristem culture, tissue culture offers several opportunities for the quick multiplication of virus-free, true-to-type propagating material and the preservation of healthy stocks. Somatic fusion, as opposed to gametic fusion, offers a method for the asexual hybridization of two protoplasts from somatic cells in order to integrate both whole genomes at intra- and interspecific as well as intra- and/or intergeneric levels (Pandey *et al*., 2010) [26]. The potato cultivars Kufri Jyoti, Phulwa, and C-13 were preserved *in vitro* using a specific MS media, allowing true to types to be regenerated for the creation of wholesome seed stock (Tiwari *et al*., 2015) [33]. According to Dwivedi *et al*. (2015) [8], double haploids are employed for inbreed development in cross-fertilizing species as well as cultivar formation in self-fertilizing species.

Future need for improvement

Despite being the world's top producer of numerous vegetables and other food crops, 43% of Indian children under the age of five are underweight, and 48%-or 61 million children-are stunted as a result of persistent malnutrition. An estimated 15% of the population is underweight and does not consume enough food, both in terms of quantity and quality. Breeders should be held accountable since India's decline from 83rd place in 2000 to 97th place in 2016 among 118 nations is worrying for the country. Vegetable improvement in India has bright future potential with a number of major areas of concentration that may support long-term agricultural growth and tackle new issues. Although the primary goal of breeding will still be to increase yield in order to fulfill the rising food demand of the people, it is crucial to produce nutrient-rich cultivars in order to guarantee health security.

We had achieved self-sufficiency in food grains through conventional breeding, but now there is a need for a second green revolution where not only production/yield but quality food is the major breeding objective. Since this cannot be realized with conventional as well as biotechnological approach alone, we must find a middle ground where we will integrate these two novel approaches for vegetable improvement. Although the study in India is still in its infancy, there is a lot of promise for combining the phenotypic and DNA data to enable breeders to make realistic selections. Future vegetable crops may be able to withstand more stress, be more adaptable, contain more nutrients, and have better processing quality. The development of vegetable varieties high in nutraceuticals and bioactive compounds suited for the fresh market has good possibilities when conventional breeding is combined with molecular biology.

Conclusion

Developing disease and pest resistance, enhancing nutritional value, enhancing quality attributes, preserving genetic diversity, involving stakeholders, and utilizing cutting-edge technologies will all be key components of vegetable improvement in India in the future. India can improve its vegetable industry, guarantee food and nutritional security, and support sustainable agriculture and public health by embracing these opportunities.

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