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Tomato (Lycopersicum Esculentum) Fruit Improvement through Breeding

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Abstract

Tomato *(Lycopersicon esculentum)* is the second most consumed vegetable in the world. Tomato *(Lycopersicon esculentum)* is self-fertilized and diploid belongs to Solanaceae family. It is richest source of vitamins, minerals as well as antioxidants (lycopene). It is also used as example plant at the level of genomic studies in research departments. Tomato *(Lycopersicon esculentum)* is grown and eaten worldwide. As we know that the more demand of tomato *(Lycopersicon esculentum)* for its nutritional value, there is needed to improve the tomato (*Lycopersicum esculentum)* varieties through modern methods of breeding and sometimes with the help of conventional breeding. Conventional breeding plays very important role to increase yield and quality. However, resistance of biotic and abiotic cannot be achieved by some methods such as conventional methods. The characters like biotic and abiotic are produced in different crops mainly by modern methods of biotechnology for example transformation, somaclonal variation, QTL mapping. Through different breeding methods, many goals are achieved and many varieties have been developed of different better traits or combine traits in same variety. Agriculture and biotechnology is trying to improve the tomatoes as per demand.

Keywords: Conventional breeding, Molecular breeding, Molecular Marker, lycopene, Hybridization, *Lycopersicum esculentum.*

Introduction

Tomato *(Lycopersicon esculentum)* very important vegetable crops. It is second most consumed vegetable after potato (*Solanum tuberosum)* in the whole world. The word tomato (*Lycopersicum esculentum)* comes from the Spanish word 'tomato' which means swelling fruit. Tomatoes can be grown under indoor and outdoor conditions. Tomato belongs to the family Solanaceae includes 3000 species [1]. Solanum Lycopersicumspecies is domesticated species of tomato. Tomato *(Lycopersicon esculentum)* first originated in South America in the area of Peru and Ecuador, but they were first domesticated in Mexico. Spanish took domesticated form of tomato (*Lycopersicum esculentum)* to Europe in 1523, Italy in 1544, England in1597 and Philippine and Malaysia in 1650. These were also taken to North America in late 18th century [2-5].

These were also taken to North America in late 18th century. There is great diversity in from very dry to very wet, from coastal to mountains and about 3300m elevation area at which it can be grown. In fact, this diversity is responsible for variation in the Lycopersicon.

Tomatoes are grown almost in all area of the world, today. Now, these have become most popular greenhouse crop in agriculture field. Tomato (*Lycopersicum esculentum)* is consumed in many forms such as raw or

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cooked and used in many dishes, sauces, salads, and drinks etc. They are commonly used as vegetable, but they are fruits and botanically classified as barriers, but it has less sugar content. Tomato (*Lycopersicum esculentum)* is a rich source of vitamin A, B, and C lycopene and beta carotene flavonoids hydroxycinnamic acid and derivatives [3,6-8]. Moreover, it is recently discovered like lycopene have antioxidative and anti-cancerous functions. Due to its high nutritive value of tomato (*Lycopersicum esculentum)*, there is increasing demand of its production. But the production is affected by many biotic and abiotic stresses i.e., disease developed by fungi viruses and bacteria and pests or high temperature, salinity and drought. However, the tomato (*Lycopersicum esculentum)* does not have high rank in nutritional value; one medium fresh tomato (*Lycopersicum esculentum)* (135 g) provides 47% RDA of vitamin C, 22% RDA vitamin A, and 25 calories. But due to volume consumed, it contributes mainly to the dietary intake of vitamins A and C as well as essential minerals and other nutrients. In the U.S. diet, tomatoes have rank first in all fruits and vegetables because of source of vitamins and minerals and phenolic antioxidants (lycopene) [9,10].

Moreover, tomato (*Lycopersicum esculentum)* is also used as model plant for research purposes related to genetics. Because it can be grown under many environmental conditions, short life cycle, insensitive to photoperiod, homozygosity, self-pollinating, diploid the reproductive potential rate is high, pollination can be controlled, hybridization and small genome. Tomato (*Lycopersicum esculentum)* can also easily regenerate due to specific characters and it allows easy grafting which helps in development and practical studies. Due to these entire characters tomato (*Lycopersicum esculentum)* crop is ideal for genomic studies [4,11].

Tomato (*Lycopersicum esculentum)* is produced in many countries but the major producers in descending order are China, USA, India, Turkey, Egypt, and Italy. Although, California and Florida are by far the leading producer of fresh and processed tomatoes [1,12-15].

Breeding in Tomato (*Lycopersicum Esculentum)*

Tomato (*Lycopersicum esculentum)* belongs to the family Solanaceae. Solanaceae family is one of the economically important families of angiosperms and contains many of the commonly cultivated plants, including potato *(Solanum tuberosum)*, tomato (*Lycopersicum esculentum)*, pepper *(Piper nigrum)*, eggplant (*Solanum melongena*), and tobacco (*Nicotiana tabacum*). Tomato (*Lycopersicon esculentum*) is diploid and self-pollinated plant having 2n=24 [16-18]. Flower of tomato (*Lycopersicum esculentum)* plant is perfect having both male and female functional part on the same flower. Tomato (*Lycopersicum esculentum)* is model plant of *Solanaceae* family for studies. In genus lycopersicum, there is both self-incompatible compatible plants and but, tomato (*Lycopersicum esculentum)* can easily hybridized with same species and also with wild varieties in suitable conditions to permit gene transfer from wild species [2].

In the last century tomato (*Lycopersicum esculentum)* breeding has been done by many standard methods i.e. pedigree method, hybridization, mass selection and backcrossing of desire characters from one parent to another which generates improved varieties of tomato (*Lycopersicum esculentum)*. Wild species of tomato (*Lycopersicum esculentum*) have been utilized in breeding programs during the past seventy years to improve the cultivated tomato (*Lycopersicum esculentum)*. Through breeding, many diseased resistant species have been evolved from wild type species. Breeding methods have been changed after the developments of molecular biology and bioinformatics [19].

These enhance the effectiveness of classical plant breeding programs. Bioinformatics and molecular tools helps to analyze large breeding problem [5].

Breeding objectives

Fruit 7ield: To increase the yield and quality of tomato (*Lycopersicum esculentum)* is the main purpose of most tomato (*Lycopersicum esculentum)* breeding programs. To increase the yield of tomato (*Lycopersicum esculentum)* and to improve its fruit quality, many beneficial traits such as disease and pest resistance, high sugar content, tolerance to abiotic stresses, are selected [20,21].

The tomato (*Lycopersicum esculentum)* breeding programs, at the University of Florida, have been introduced the new variety of tomato which is heat and drought resistance. Due to its trait tomatoes can grow under the hot condition. This has been done by breeding. There are some difficulties to achieve the better yield these difficulties are overcome by the identification of molecular markers. Molecular markers identify the beneficial traits which can improve the yield of tomato. Disease resistant trait is beneficial to increase the yield. In this way, abiotic stresses tolerance also increases the yield of crop. Due to these specific traits plant can grow in hard conditions it may warm or cold [22-25].

Fruit quality: Breeding objectives include characteristics shape, size and color and some chemical factors like soluble solids, acidity, taste and sensory factors. To increase the shelf life of fruit is also goal of tomato breeding program [26]. And it allows focus on the fruit ripening. Fruit ripening also affect the other traits like color flavor and soluble solids. Flavor is actually the sum of the sugar and acid and set of the 30 volatile compounds. Flavor is a trait which is so complicated. By genetic engineering, flavor of tomato fruit increased by increasing the sugar and acid contents. The nutritional quality of tomato determine by the lycopene, carotenoids, vitamin A and vitamin C contents [27].

Nowadays, scientists are working on tomato (*Lycopersicum esculentum)* fruit to increase the content of lycopene and carotenoids. Wild species have been identified which are rich in lycopene*. S.pimpinellifolium* is five times higher in lycopene level than the cultivated tomatoes [28].

Disease and pest resistant

It is common objective to breeding in food crops to produce or develop resistance against many disease and pests. The main objective of disease-resistant character is to reduce the use of pesticides chemicals to control the disease-causing agents. Disease resistance genes can be added from wild species to cultivated species of tomato (*Lycopersicum esculentum)* by traditional and modern methods of breeding [2,29]. By knowing the whole sequence of tomato genome many molecular markers are available to improve the varieties. After knowing the knowledge of process and protocols of lab, greenhouses and molecular markers provided by The World Vegetable Center many resistance verities of tomatoes have been developed against many disease i.e. late blight of tomato yellow leaf curl, bacterial wilt, tobacco mosaic viruses. Many pests resistance gene have been inserted wild verities to cultivated verities [1,30].

During the past decades, the emergence of molecular markers and Marker Assisted Selection techniques have provided gene identification and mapping and inserting many disease resistance genes and quantitative trait loci (QTLs) in tomato (*Lycopersicum esculentum)*. Now the use of marker technology in disease resistance breeding in tomato (*Lycopersicum esculentum)* is becoming a usual procedure. Resistance against insects and insect's disease not yet developed because of insects can be controlled by many chemical and insecticides and pesticides [31-33].

Tolerance to heat and drought stresses

Heat and drought are the major abiotic stresses that affect the production of tomato (*Lycopersicum esculentum)* in some areas. Heat is the main stress in the tropical and sub-tropical area. This required combination of traditional breeding methods a marker-assisted selection. Mutation breeding is used to combat heat and drought stresses in food crops [34]. Heat affects the ripen pollen and so produces nonviable pollens and also affect the number of pollens. However, there is less research is done on drought and heat resistant traits and required succeeded, proper and long–term research and methods to combat the abiotic stresses [2].

Breeding methods

Conventional breeding: Breeding has based on standard methods which are Mass selection, Pedigree, and Hybridization. These are all conventional methods for breeding. Conventional breeding has developed the cultivars and also dominant resistance genes to control pest and disease [35]. The replacement of inbred lines with hybrids increases the yield and other beneficial traits of tomato (*Lycopersicum esculentum)*.

Mass selection: Mass selection is basically a breeding method. Through this method, tomato (*Lycopersicum esculentum)* fruit quality and yield can be increased. In this method, phenotypically better plants are selected and they grow in bulk. And again, phenotypically better plants are grown, and this is repeated again and again till the desired characters are developed. In this way, quality and fruit yield are increased. In this way, desire characters are combined and developed new varieties [36,37].

Pedigree method: In the pedigreemethod, the controlled cross between the plants is carried. And by individual plant selection, the desirable trait is obtained, and inbred lines are prepared by growing them in lines and rows through successive generations. This method is beneficial and reliable to develop new varieties of the tomato crop. This method develops new cultivars faster than mass selection. This is done by selecting individual plants in the early generation [38].

Hybridization: Hybridization mostly done in the cross-pollinated crops. But it is also done in some cross-pollinated crops just like tomato (*Lycopersicum esculentum)*. And introduce many other tomato (*Lycopersicum esculentum*) varieties. But it needs some hard work and pollination is done by human intervention in tomato (*Lycopersicum esculentum)*. Tomato (*Lycopersicum esculentum)* is self-pollinated crop while tomato (*Lycopersicum esculentum)* varieties can be developed through hybridization. First of all, inbred lives are produced by self-crossing.And then cross the inbred lives of different varieties and grow plants and the plants are selected which have traits which are required. Sometimes undesirable traits are also transfer with the desirable traits then these undesirable traits are eliminated by backcrossing method although this is time-consuming [2,4].

Molecular breeding: There are some methods that used to modify our crop plants are: Molecular markers, Quantitative traits locus, Genetic engineering, polymerase chain reaction. These methods have been for many purposes such as estimation of genetic variability, identification of genotype and determination of the sequences of useful genes. These techniques are also helpful for the estimation of genetic distances between population and breeding materials. Molecular markers technique is one of the important methods to modify our crop plant.It is widely used for breeding tomato. Many genes used that confer resistance to crucial categories of tomato (*Lycopersicum esculentum)* pathogens and these are very perfectly mapped and cloned. Maps are developed that allowed for "pyramiding" resistance genes in tomato (*Lycopersicum esculentum)* through the mass assisted selection. This method is need to the capacity for high-throughput analyses at low quality and low cost. For practical uses, it is most crucial method. This technique is also helpful and available to handle the efficiently large amounts of material at very low costs. If we want to get the specific needs for modification the molecular applications in practical plant breeding. Molecular marker techniques for plant breeding are useful in order to increase their availability to breeding programs [5]. Isozyme molecular maker is one of the best marker types to breeding of tomato (*Lycopersicum esculentum)*. It is helpful for study the genetic variation between cultivated and wild species of tomatoes. Isozyme used for molecular linkage mapping and breeding purposes. Rare Isozyme alleles provide more perfect results for resistance purposes. Specific region of the tomato (*Lycopersicum esculentum)* genome and uni-gene sequence are needed to association of the Isozyme marker [6].

Quantity traits locus

Quantitative Trait Locus in which location of a specific gene that affects a measurable trait. These traits are affected by many genes and also by the environment. Quantitative traits are used for plant height as measured on a ruler and body weight as measured on a balance. In 1930s the mapping of tomatoes is started. In 1970s the tagging of single gene traits with the help of molecular markers is started [2].

QTLs mapping is very efficient in tomato (*Lycopersicum esculentum)* breeding as we using the marker-assisted selection.QTL technique used for biotic, abiotic stresses and for fruit traits. In great amount of the QTLs indicate in the tomatoes which are responsible and control the following traits as fruit color, shape, size, quality as well as seed yield [3]. However, only single gene is responsible to so many disease for resistance/cure. With the help of QTLs analysis, selection of superior group of traits through the crosses between the pure line/modified seed and also helpful for the polygenetic durable resistance gene analysis. QTLs are also efficient for the genetic controls [7].

DNA markers

These markers have much capacity fordevelopment in breeding programs. Only 5-6% variations are shown in cultivated species besides that, wild species of tomatoes having 95% of the variation in their germplasm. Some DNA markers are localized at cytoplasmic (mitochondrial and chloroplastic DNA) in the tomato (*Lycopersicum esculentum)*, consecution of cDNA and genomic libraries [8].

Genome sequence of tomatoes

Tomato (*Lycopersicum esculentum)* is an informative crop plant. It may be strength material as to finding genetic variation and diversity. In 2003 a project named international *Solanaceae* genome project which is doing their best job to achieving the high-quality genome sequence in the tomato plant. This project hasa big goal, tomato chromosomes which contain some genes having rich euchromatic portion are sequenced. 12 chromosomes are present in the tomato (*Lycopersicum esculentum)* genome which having 950 megabase unit of DNA fragment.

Genetic engineering

This technique is used to modify the tomato (*Lycopersicum esculentum)* plant and it is helpful for the disease resistance. Lin et al. [7] performed an experiment which is helpful for the resistance of bacterial and fungal diseases. In tomato (*Lycopersicum esculentum)* cultivar a gene pr1 which is introduced and that gene used to the resistance of tomato mosaic virus. The result was observed as in four generations there will find that the transgenic lines with gene NPR1 were all normal in morphology. Tropoviruse is causing a limiting factor in tomatoes plant and according to an experiment that is performed to great resistance against tropoviruse. With the help of antisense methodology tomatoes plant shown resistance against leaf curl disease. The generating plants of the transgenic methodology is greatly beneficial to tomato (*Lycopersicum esculentum)* plant against insect attack. Cry1A protein is carried by the transgenic plants, which is more effective against *Helicoverpa Nigeria* [8].

Somatic hybridization

Somatic hybridization technique is used to develop a hybrid between tomato (*Lycopersicum esculentum)* and potatoes. In the tomato (*Lycopersicum esculentum)* plant breeding, this hybridization had great demand. Wild species of the tomatoes varieties have more success to regeneration from protoplast than the cultivated species. The symmetry and asymmetry hybrid are produced between two varieties of tomatoes with the help of protoplast culture. Genetic engineering may replace with somatic hybridization is due to vigorbehavior is occur in hybrids of some species of tomatoes [9].

Marker-assisted selection in tomatoes breeding:

The relationship between phenotype and the markers is only possible through the development of markers/ linkage maps. The using of marker-assisted selection is one of the known methodsof finding the chromosomal segment which having marker and the identification of the traits. Caps (cleaved amplified polymorphic sequence) is the other form of the simple PCR marker. Here another marker named SCAR (sequence characterized amplified region) which is used as the DNA marker in case of breeding of crop plants. This is very efficient to enhance breeding programmes. One of the best examples of plant breeding that may change from the selection of phenotype towards the selection of genes with the help of marker-assisted selection [10].

Achievements through breeding

Many varieties of improved characters have been developed through different breeding methods. Indian and American organization play a vital role in making new varieties. Most of the varietieslike Pusa Ruby, Pusa Early Dwarf, Hisar Arun, Hisar Anmol, Pusa Hybrid-1, Pusa Divya, Arka Vikas, Roma, Sioux, Rakshita, Naveen and NDT 5, are developed through conventional methods.

Conclusion

Tomato (*Lycopersicum esculentum)* is the most important of all the cultivation crops. Tomato (*Lycopersicum esculentum* is the self–pollinated crop and has vitamins, minerals and an antioxidant against diseases like heart disease etc. Tomato (*Lycopersicum esculentum)* have a considerable importance. Market demands of this fruit are long shelf life, its shape, and color, in terms of quality and fruit flavor should be sweetness and juiciness. For *Solanaceae* family, tomato (*Lycopersicum esculentum* genome has been selected due to its small genome size, short reproduction period and due to its diploid genetics. The breeding goals are fruit yield and resistance to disease and pests. Until now achievements in tomato (*Lycopersicum esculentum)* breeding are depends on breeding methods. In plant breeding, molecular techniques opened new pathways for crop improvement. During last two decades, notable progress in molecular genetics has been confirmed including, cloning of gene, DNA sequencing, mapping of genes, QTL analysis, and markers development. Now, Functional genomics can be used for marker development. Transformation is also enterprising in development of marker. In many countries like in Europe, in spite of its rejection, economically it this is very important in nutraceuticals and pharmaceuticals. QTL analysis has very important impact on breeding programs. Many complex traits of fruit can be determined by this method. In next decades conventional breeding methods will not increase the production. Therefore, traditional breeding methods like Marker-assisted selection would be important tool for crop improvement. In future, tomato (*Lycopersicum esculentum)* genome sequencing of gene-dense region will be determined.

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