Int.J.Curr.Microbiol.App.Sci (2019) *8*(3): 1275-1283

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 8 Number 03 (2019)**
Journal homepage: http://www.ijcmas.com

Review Article https://doi.org/10.20546/ijcmas.2019.803.151

Recent Advances in Breeding of Tomato- A Review

Payal Sharma, Seema Thakur* and Radhika Negi

Krishi Vigyan Kendra, Solan at Kandaghat, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India
**Corresponding author*

Keywords

Tomato, Wild type, Self pollination, Floral biology, Flavour

Article Info

Accepted:
15 February 2019
Available Online:
10 March 2019

A B S T R A C T

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops under solanaceous group which can be grown both under open field conditions and greenhouses. Tomato has achieved high popularity especially in the recent years because of lycopene's anti-oxidative activities and anti-cancerous functions. The cultivated tomato has been used in genetic studies because of the ease with which it can be easily manipulated and also its diversity present within the population. The most important breeding techniques used in order to improve tomato has been the method of hybridization followed by pedigree selection. Among all the methods, the back cross method of breeding has been used to transfer the desirable traits from the wild species to cultivated varieties. Breeding methods like pedigree methods, single descent method in combination with the molecular approaches have been found to be useful. Tomato has presented as an example for gene transfer from uncultivated into cultivated cultivars for development of improved varieties of the qualitative traits. Till now the achievements are through different traditional breeding methods. It is the need of the hour to use the traditional method in combination with the recent approaches which takes less time to develop a variety. The population of the country is increasing day by day and to meet the requirement of the whole country, breeder need to develop the high yielding varieties by the use of the combined application of traditional breeding and plant biotechnology methods. Marker-Assisted Selection might prove to be a valuable tool for tomato breeding

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops under solanaceous group which can be grown both under open field conditions and greenhouses. It has become an important commercial crop when we talk about the human nutrition. It has more than 3000 species among solanaceous vegetables. Tomatoes were originated in Peru (South America) and first domesticated in Mexico on the basis of availability of numerous cultivated and wild relatives of the tomato found in this area (Rick. 1969). There are two types of tomatoes that are cultivated and wild form tomatoes. The genetic diversity in the wild type of tomatoes, especially in case of self-incompatible species such as *S. chilense* and *S. peruvianum* are very vast. This crop is widely grown throughout the tropical and subtropical areas around the world. Tomato is considered as a protective food because it provides nutrients such as beta-carotene, lycopene, vitamin C and flavonoids. Furthermore, tomato has achieved high popularity especially in recent years because of lycopene's anti-oxidative activities and anti-cancer functions (Fentik *et al.*, 2017).Tomato fruits were very small berry and were considered as poisonous in the ancient times but in 1820, farmer R. G.

Johansson made people aware that tomato fruits were not poisonous. The growing habit of tomatoes can also be distinguished on the basis of the indeterminate or determinate type. The plants have compound, alternate leaves with small leaflets. The stem is erect to semierect. It is soft and hairy when young and hard, woody and branched when mature. It has a strong tap root system with a highly branched system of fibrous and adventitious roots. Cultivated tomato is a self pollinated crop as the stigma is inside the anther cone but in case of some wild forms the stigma is exerted outside the anther cone which leads to cross pollination (Cheema *et al.*, 2004)

The demand for tomatoes is increasing day by day but as its production is affected by many diseases and stresses (biotic and abiotic stress). Moreover, there are many factors, which are also responsible for the limited production and growth of tomato such as drought, high or low temperature, salinity and insect and pest attacks. The development of disease resistant and stress tolerant varieties are main objectives for plant breeding. Genetic engineering techniques can also play an important role in the improvement and development of disease resistant cultivars. So, now days it is becoming obvious that improvement of this crop is a critical task to overcome the limitation of tomato production (Fentik *et al.*, 2017).

Morphology

Tomato is an annual plant about 3 m tall and its leaves are compound, pinnate, alternate with small leaflets. These leaves are oblong to ovate in shape with irregularly toothed margin. There are also some varieties in tomato where the margins are smooth. The petiole is long as compared to the leaves and the main leaf have very short stalk. Stem is soft and hairy when young and hard, woody and highly branched when mature. Tomato has an important strong tap root system with a highly branched system of adventitious and fibrous roots. When there is any injury to the main root system of the plant the adventitious roots develops very rapidly and act as a support system (Cheema *et al.*, 2004).

It is a self pollinated crop and self pollination is favoured by the position of stigma within the anther cone and also due to the pendant position of the flower. Determinate and indeterminate are the two growing habits found in tomato. It has hypogynous and perfect flowers which are borne on the short pedicle with cyme Inflorescence. Berry have many seeds which are light brown or golden yellow in colour with 2-4 locules and fruits when ripe they appear to be orange, red or yellow. The tomato plants can be grouped into three major groups that are fruiting habit, fruit shape and presence or absence of ridges on the fruits (lawal *et al.*, 2007).

Tomato (*Solanum lycopersicum* L.) fruits are very distinct in shape and size, differ from round and small to large or may have other variable shapes. The major loci that have been identified as contributing to an elongated shape in tomato are ovate (Ku *et al.*, 1999; Liu *et al.*, 2002; Van der Knaap *et al.*, 2002), sun (Van der Knaap and Tanksley, 2001; Van der Knaap *et al.*, 2002, 2004).

There are two varieties show utmost fruit shape characteristics are *S. lycopersicum* cultivars Banana Legs and Howard German. There is difference between the fruit shape of undocile accessions and cultivated tomatoes that the former one has elongated fruits. Both varieties Banana legs and Howard German bear fruits that are elongated in shape (Brewer *et al.*, 2006). There were four major loci found to control multiple fruit shapes, canonical variates and principal components present in the populations.

Floral biology

The cultivated tomato has been used in genetic studies because of the ease with which it can be easily manipulated and also its diversity present within the population. Tomato has perfect flowers, having viable male and female parts. In tomato anthesis starts around 6 a.m and finally the flower opens around 11 a.m, dehiscence of anther occur between 8 to 11 a.m. Pollen remain viable from 2 to 5 days. Stigma of the flower remains receptive 16 to 18 hours before anthesis upto 6 days after anthesis (Cheema *et al.,* 2004).

The reproductive biology and production of appreciable quantity of seeds per fruit provide ample opportunity for manifestation of heterosis in tomato (Singh and Singh, 1993). Under the favourable environmental condition more than 250 seeds may be obtained from a single pollination. In tomato emasculation for controlled pollination must be done nearby one day prior to opening of the flower in order to avoid the self-pollination. Making controlled pollinations under greenhouse is more efficient than under field conditions environments. The stigma appears to be fully receptive at this stage, thus allowing pollination immediately after emasculation. Emasculation of flower is done between 55 and 65 days after planting. Pollen grains are collected before it is shed. When the corolla of the emasculated flower turns bright yellow the stigma is ready for pollination. For 3-5 weeks repeat the pollination 2-3 times a week. Usually, fruit starts to enlarge after successful pollinations are visible within one week (Fentik *et al.,* 2017).

Objectives of plant breeding

Needs of producers, consumer and processors include breeding for processing (TSS, color, total acidity and viscosity) Panchal *et al.,* (2017) evaluated tomato genotypes in order to estimate the extent of heterosis and quality traits like, TSS, lycopene content, ascorbic acid content (vitamin-C), average pulp content, pulp: skin ratio, solid: acid ratio and titrable acidity and cross JTL-12-12× JT-3 followed by NTL-1 × AT-3, JTL-12-12 × GT-2 shown positive significant heterosis for all the traits., fresh market (shelf life for distance transport, round fruit and large size), home gardens (high fruit quality, appropriate disease resistance and earliness) and green house production of tomatoes (high yielding for several successive markets and indeterminate), are the general breeding objectives. Some of the major specific objectives are Fruit yield, Earliness, Growth habit, Fruit quality, Resistance to diseases and pest, Resistance to abiotic stresses and Suitability to post harvest storage and transport. The fruit quality now days becoming one of the important breeding objectives which include following studies (Ramachandaran, 2013).

Appearance: external colour, smoothness, size, shape uniformity, free from defects are major concerns.

Colour: major genes, affecting for fruit colour in tomato have been identified as crimson and high pigment (hp) to enhance fruit quality.

Texture and firmness: fruit texture, notably firmness and the ratio of fruit wall to locukar content plays an important role for quality as perceived by consumer of fresh tomatoes.

Flavour: sugar and organic acid are important determinants of tomato flavor. The proper balance of these constituents is required to give optimum flavor where as intensity of flavor (sweetness or sourness) is a result of relative level of these constituents.

Nutritive value: Tomato is significant source of vitamin A and C in human nutrition, wide range of genetic variation exists in tomato for these nutrients. Plant carotenoids represent major pigment in tomato fruit. On oxidation of beta carotene (an orange pigment) yields two molecules of vitamins. Certain carotenoids in tomato fruit also converted to vitamin A. but some lycopene, the major pigment of red fruited cultivars has no provitamine A activity, but some orange fruited cultivars has such activity. There is also a wide range of fruit ascorbic acid (vit C), the level of genus lycopersicon (10-20mg/ 100g fresh weight), but linkage between high ascorbic acid with small fruit size is the limitation.

Ripening: Tomato must be slow ripener in order to increase its self life.

Breeding methods used in tomato

The most important breeding techniques used in order to improve tomato has been hybridization followed by pedigree selection. Among all the methods the back cross method of breeding has been used to transfer the desirable traits from the wild species to cultivated varieties. Breeding methods like pedigree methods, single descent method in combination with the molecular approaches have been found to be a useful (Fentik *et al.*, 2017).

Introducing a genotype or a group of genotype of plants into new agro climatic condition where they have not been grown before. In this method the seeds are introduced in the new area and the better plants are further evaluated. These evaluated plants if meets the standards are directly released as a variety or used in hybridization for crossing. There are varieties which are introduced from the foreign countries called as exotic varieties and these varieties are used to improve the existing varieties. Introduction can be done between two continents, two counties, two states or two districts. There are many varieties of tomato that are introduced from one area to another in order to test its adaptability, hence use it as a variety in that particular area.

IARI and other institutes introduced many varieties are Roma, Labonita, Sioux, Marvel, Best of All and Money maker.

Pure Line Selection

A pureline is a progeny of single homozygous plant of a self pollinated crop therefore all the plants in a pureline are genetically same. In this method a large number of phenotypically superior plants are selected from a self-pollinated crop and these plants are further harvested individually. The individual plant progenies are planted in the progeny test in order to test the homozygosity of the plants and then these plants are evaluated. The best progeny after evaluation is selected from the population and is released as a variety. The last population which we get after so many years of evaluation is pureline that is all the plants have same genotype (Table 1).

Mass selection

Mass selection involves selection of a large number of phenotypically superior plants. Harvesting and bulking the produce of the selected plants together for sowing the next generation. This process of harvesting and bulking is repeated till the desired characters are obtained. The original population from where the superior plants are selected would have been a mixture of several purelines, and the plants selected would be homozygous. The final population which is obtained from the selected plants would be more uniform than that of the original population for easily observable characters which are governed by

one or few major genes like presence of awns, plant height and seed colour (Table 2 and 3).

Pedigree method

Pedigree may be defines as a description of the ancestors of an individual and it generally goes back to some distant ancestor or ancestors in the past. This is the most favourite method of breeders as it tells the changes that occur from earlier time till now. It is useful by finding out if 2 individuals are related by descent, whether they have a common parent in their ancestor and some genes in common. Pedigree would describe the parents, Grand parents, Great grand parents and so on. This method make a controlled crosses followed by single plant selection. Single plant selection is initiated in F_2 and is continued through successive generations till F_6.

Backcross Method

Backcross is a cross between a hybrid and one of its parents. Hybrid and the progenies in the successive generation are repeatedly backcrossed to one of the parents. This method is commonly utilized in desirable gene transfers for resistance to diseases like, early blight resistance, Bacterial wilt resistance and nematode resistance. This method is used for development of isogenic lines, multilines and also Root Knot Nematode lines are derived from *S. peruvianum.* The end product of backcross method is similar to parent variety except for the character which has to be transferred from the donor source. Segbefia *et al.,* (2013) studied backcrossing method to develop lines which combines resistance to TYLCV disease derived from (*Solanum pimpinellifolium*) and good fruit qualities derived from (*Solanum esculentum*). Though environmental factors hindered success rates (36.47%) of the backcrosses but field backcrosses could be a useful tool for researchers who do not have access to modern breeding techniques to recover a few genes from the local well adapted variety.

Heterosis breeding

Heterosis in tomato was first observed for higher yield and more number of fruits. Since then, heterosis for yield, its components and quality traits were extensively studied (Ahmed *et al.,* 2011; Kurian *et al.,* 2001). Tomato is an important example of self pollinated vegetables where heterosis is being exploited on commercial level. Hedrick and Booth (1907) were the first to report the presence of heterosis in tomato. When F1 progeny is better than the parents is called as heterosis. Heterosis is also called as true heterosis / euheterosis. Heterosis is used for, locule number, fruit number, plant height, number of branches, fruit size, fruit yield, ascorbic acid, pH, TSS. Savale *et al.,* (2017) estimated that AVTO-5 x GT-2 showed high SCA effect for fruit yield over environments. The maximum standard heterosis over commercial check abhinav was exhibited by the cross AVTO-5 x GT-2 followed by AVTO-7 x GT-2, AVTO-5 x JT-3, JTL-12-12 x GT-2 and JTL-12-12 x JT-3 for fruit yield and its one or more important component traits. Gautam *et al.,* (2018) evaluated tomato lines with parents for heterotic manifestation of yield and yield attributing characters. Three promising crosses *viz.,* UHFT-9 x SolanLalima, UHFT-10 x SolanLalima, and UHFT-22 x SolanLalima were identified for developing high yielding F1 hybrids/ varieties of tomato with many desirable horticultural traits (Table 4).

Interspecific hybridization

This is the method in which two different species are crossed to get a desired product. There are sources from which breeders can take a desired gene of interest to make a

disease, salinity or drought resistant variety (Selvakumar, 2014). *S. peruvianum*: Source for resistance to Verticillium wilt, TLCV, nematode and salinity. *S. pimpinellifolium*: Source of Bacterial wilt Vit C and carotene content. *S. hirsutum*: Source of Fusarium wilt, insect. *S. cheesmanii*: Source of salinity resistant. *S. pennelli*: Source of Drought and Salinity (Table 5).

Mutation breeding

Mutation breeding now days is used as an important tool to develop a variety in a very short time by the breeders. When the mutation is induced by using various chemicals for crop improvement is called mutation breeding (Table 6).

Tomato varieties tolerant to abiotic stresses

kissoudis *et al.,* (2016) evaluated the effect of different levels of salt stress ranging from mild to severe (50, 100, and 150mM NaCl) on powdery mildew resistance. In susceptible and partial resistant lines, increased susceptibility was observed under mild salt stress (50mM) which was accompanied by accelerated cell death-like senescence and severe salt stress (150mM) reduced disease symptoms. These results highlight the significance of stress severity and resistance type on the plant's performance under the combination of abiotic and biotic stress (Table 7).

Table.1 IIHR Bangalore developed varieties through pureline selection

VARIETIES	SOURCE	CHARACTERISTIC
ArkaVikas	PLS from Tip-Top (USA)	Rainfed variety
ArkaSaurabh	PLS from V-685 (Canadian Breeding line)	Suitable for fresh and long transport
ArkaAbha	PLS from VC-8-12-1 (AVRDC, Taiwan)	Resistant to bacterial wilt
ArkaAlok	PLS from CL-144-5-1-0 (AVRDC, Taiwan)	Resistant to bacterial wilt
ArkaAhuti	PLS from Ottawa-60 (Canada)	It is good for processing

Table.2 Mass selection

VARIETIES	SOURCE
Arka Ashish	Massing of IIHR-674 from VC-82 line from USA

Table.3 IIHR and IARI have developed varieties through mass selection

VARIETIES	SOURCE	INSTITUTE
Arka Meghali	ArkaVikas X IHR 554	IIHR, Banglore
Pusa Ruby	Meeruti X Sioux	IARI, New Delhi

Table.4 IIHR and IARI have released varieties through heterosis breeding-

Varieties	Source	Institute
Arka Vishal	IHR-837 X IHR-932	IIHR, Banglore
ArkaVardan	IHR-550-3 X IHR-932	IIHR, Banglore
ArkaShreshta	15-SBSB X IHR-1614	IIHR, Banglore
ArkaAbhijit	15- SBSB X IHR-1334	IIHR, Banglore
ArkaSamrat		IIHR, Banglore
ArkaRakshak		IIHR, Banglore
ArkaAnanya	Resistance to TOLCV and Bacterial wilt	IIHR, Banglore
PusaDivya	Long style X Roma (Developed using male sterile line, anther less mutant.)	IARI, New Delhi
Pusa Hybrid-1	PusaSheetal X Chikoo (Fruit set at high night temperature)	IARI, New Delhi
Pusa Hybrid-2	Highly tolerant to root knot nematode	IARI, New Delhi
Pusa Hybrid-4	Pusa-120 X Chikoo (Highly tolerant to root knot nematode)	IARI, New Delhi
Pusa Hybrid-8		IARI, New Delhi

Table.5 IARI and CCSHAU have developed the varieties through Interspecific hybridization-

Varieties	Source	Institute
Pusa Red Plum	*S. Lycopersicum* X *S. pimpinellifolium*	IARI, New Delhi
HisarAnmol	Hisar Arun X *S. hirsutum f. glabratum*	CCSHAU, Hisar

Table.6 IARI and TNAU released varieties through mutation breeding-

Varieties	Source	Institute
Pusa S12	Sioux	IARI, New Delhi
PusaLal Meeruti	Improved Meeruti (seeds were exposed to 15-30 kv. of ϒ-rays)	IARI, New Delhi
CO-3	Mutant of CO-1	TNAU, Coimbatore
PKM-1	Mutant of Annanii	Coimbatore

Table.7 IARI, UHF and HAU have released abiotic tolerant varieties-

Abiotic tolerant varieties	Source	Institute
Low temperature	Pusa Sheetal	IARI, New Delhi
Drought	SolanVajr	UHF, Nauni
High temperature	HS-101, HS-102	HAU- Hissar
Salinity	Pusa Ruby	IARI, New Delhi

Future prospects

Tomatoes are presented as an example for gene transfer from uncultivated into cultivated cultivars for development of improved varieties of the qualitative traits. Till now the

achievements are through different traditional breeding methods so question arises why not we use the traditional method in combination with the recent approaches which takes less time to develop a variety. It is now rightly said that the population of the country is increasing day by day and to meet the requirement of the whole country breeder need to develop the high yielding varieties which is not possible with the traditional breeding methods. Use of molecular marker techniques are established therefore, the combined application of traditional breeding and plant biotechnology methods including selection based on molecular markers marker-Assisted Selection might be valuable tools for tomato breeding (Fentik *et al.,* 2017).

References

Gautam N, Kumar M, Vikram A and Sharma S. 2018. Heterosis Studies for yield and its Components in tomato (*Solanum lycopersicum* L.) under North Western Himalayan Region, India. *International Journal of Current Microbiology and Applied Science* 7:1949-1957.

Sevale SV, Patel AI and Sante PR. 2017. Study of heterosis over environments in tomato (*Solanum lycopersicum* L.). *International Journal of Chemical Studies* 5:284-289.

Van der Knaap E, Tanksley SD. 2001. Identification and characterization of a novel locus controlling early fruit development in tomato. *Theoretical and Applied Genetics* 103, 353–358.

Van der Knaap E, Lippman ZB, Tanksley SD. 2002. Extremely elongated tomato fruit controlled by four quantitative trait loci with epistatic interactions. *Theoretical and Applied Genetics* 104, 241–247

Van der Knaap E, Sanyal A, Jackson S, Tanksley SD. 2004. High-resolution fine mapping and fluorescence in situ hybridization analysis of sun, a locus controlling tomato fruit shape, reveals a region of the tomato genome prone to DNA rearrangements. *Genetics* 168, 2127–2140.

Ku HM, Doganlar S, Chen KY, Tanksley SD. 1999. The genetic basis of pear-shaped tomato fruit. *Theoretical and Applied Genetics* 99, 844–850.

Liu J, Van Eck J, Cong B, Tanksley SD. 2002. A new class of regulatory genes underlying the cause of pear-shaped tomato fruit. *Proceedings of the National Academy of Sciences,* USA 99, 13302–13306.

Rick CM. 1969. Origin of cultivated tomato, current status and the problem. *International Botanical Congress* pp.180.

Kurian A, Peter KV and Rajan S. 2001. Heterosis for yield components and fruit characters in tomato. *Journal of Tropical Agriculture* 39:5-8.

Singh RK and Singh VK. 1993. Heterosis breeding in tomato (*Lycopersicon esculentum* Mill.). *Annals of Agricultural Research* 14:416-420.

Fentik DA. 2017. Review on Genetics and Breeding of Tomato (*Lycopersicon esculentum* Mill.). *Advances in crop Science and Technology* 5:5.

Panchal BB, Gurjar, Tulsi D, Kalaria, VD and Patel NB. 2017. Study of heterosis Breeding for Processing Characters in Tomato (*Solanum lycopersicum* L.). *International Journal of Pure and Applied Bioscience* 5:592-600.

Sebefia MM, Klu GYP, HM, and Amoatey. 2013. Developing tomato breeding lines resistant to Tomato Yellow Leaf Curl Virus (TYLCV) Disease and of good fruit quality through backcrossing. *School of Nuclear and Allied Sciences, University of Ghana, Legon. Box LG 80, Legon- Accra,*

Ghana pp. 1-9.

Cheema DS and Dhaliwal MS. 2004. *Hybrid Tomato Breeding*. Food Products Press, an imprint of the Haworth Press, Inc pp. 1-14.

Ramachandran RK. 2013. *Breeding of Vegetable Crops*. Narendra Publishing House pp. 29-38.

Ahmad S, Quarmruzzaman AKM and Islam MR. 2011. Estimate of heterosis in tomato (*Solanum lycopersicum* L.). Bangladesh Journal of Agricultural Research 36:521-527.

Kissoudis C, Sunarti SS, Weil CVD and Visser RGF. 2016. Responses to combined abiotic and biotic stress in tomato are governed by stress intensity and resistance mechanism. *Journal of Experimental Botany* 67:285.

Brewer MT, Moyseenko JB, Monforte AJ and Knaap EVD. 2007. Morphological variation in tomato: a comprehensive study of quantitative trait loci controlling fruit shape and development. *Journal of Experimental Botany* 58:1339-1349.

Lawal OJ, Ayodele and Chukwuka KS. 2007. Morphological studies in *Lycopersicon esculentum* Mill. Lines in Southwestern Nigeria. *Journal of Biological Sciences* 7:737-744.

Selvakumar R. 2014. *Glaustas Olericulture*. New Vishal Publications E-153, West Patel Nagar, New Delhi pp. 591.

How to cite this article:

Payal Sharma, Seema Thakur and Radhika Negi. 2019. Recent Advances in Breeding of Tomato- A Review. *Int.J.Curr.Microbiol.App.Sci.* 8(03): 1275-1283.
doi: https://doi.org/10.20546/ijcmas.2019.803.151