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Tomato Leaf Curl Disease: A Review

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ABSTRACT

Tomato is a most economic vegetable in India. Covers major area in its cultivation during crop production, it is threatened by major viral disease *i.e* tomato leaf curl disease, caused by begomovirus and transmitted by the vector. It causes yield loss up to 90-100 per cent, application of insecticide for the control of vector causes regular outbreak. Identification of resistant source from wild species and their introgression with susceptible source, development of lines/varieties, resistant/tolerant to Tomato leaf curl disease is the safest and long term alternative for solving this problem. This paper covers the major aspect related to virus, virus causing factors, vectors and sources of disease resistance and also breeding tools employed for its resistance and some of the barriers in breeding programme.

Key words: Genetics and sources of resistance, Solanum lycopersicum, Screening, ToLCV.

Tomato (*Solanum lycopersicum* L.) is one of the most popular solanaceous vegetable widely grown in India. It is one of the most important protective food because of its high nutritive value, fruit is good source of vitamin A, C and also contains fibers, organic acids and antioxidants. In India tomato is grown in an area of 812.00 m.ha with a production of 205.73 mt. Andra Pradesh, Madhya Pradesh, Karnataka and Gujarath are the major producing states (Anonymous, 2018). Intensive cultivation of tomatoes in some areas has lead to a significant increase in farmer's income, but a complex of pests and diseases threatens its production and productivity. In India major constraint for tomato production is regular outbreaks of tomato leaf curl virus disease (Saikia and Muniyappa 1989; Ramappa *et al*., 1998) and causes yield loss to an extent of 100 per cent during summer (Mishra *et al* 2014). Tomato leaf curl disease can be effectively managed by control of vectors *i.e Bemisia tabaci,* by the application of pesticides, use of physical barriers like nylon nets (Muniyappa *et al*., 2002) and botanicals like neem leaf and garlic cloves extract as an alternative to pesticides (Mirza *et al*., 2018). However use of plant protection chemical is not economical because of higher cost of chemical, residual effect and ultimately affect the human health. Hence development of resistant lines or varieties is more important through different breeding methods, by introgressing the resistant gene from different sources.

Symptomology

Tomato leaf curl virus infected plants produce disease symptoms like clearing of veins, reduction in leaf size, stunted growth, deformation of leaf lets, inward and outward curling and puckering of leaflets. The infected plants produced only few fruits in case of late infection and no fruits, at very early stage of infection. The diseased plants usually developed purple patches especially on older leaves (Vasudeva and Samraj 1948; Sastry and Singh, 1973, Saklani and Mathai, 1977; Raychaudhary and Nariani, 1977; Capoor, 1981; Saikia and Muniyappa, 1989).

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Vector and virus

Tomato leaf curl disease is caused by the *Begomovirus* belongs to the family *Geminiviridae* and transmitted by the vector white fly (*Bemisia tabaci* Gen.). The wide range of geographical distribution with variety of host range makes it difficult to control (Naresh *et al*. 1980).

ToLCV genome is composed of circular single stranded DNA molecule of 2800 nucleotide which is monopartite (Tomato leaf curl Karnataka and Bangalore virus) found in southern parts of India (Abinder *et al*., 2009). Bipartite begomovirus (Tomato leaf curl Delhi, India and Gujarat virus) has DNA-A and DNA-B components and found most commonly in northern parts of India (Pandey *et al*., 2010). Chowdareddy *et al*. (2005) reported that in South India, tomato leaf curl Bangalore virus4 (ToLCV- Ban4) is most predominant.

The TYLCV genome consists of six open reading frames (ORFs), these open reading frames encode proteins for encapsidation (CP), movement of virus particle (MP), replication initiator (Rep), transcriptional activator (TrAP),

replication enhancer (REn) and a determinant for expression of symptom and virus spreading (C4). They are partially overlapped and organized in two transcriptional directions, separated by a conserved inverted repeat termed intergenic region (IR) (Gronenborn 2007). All the six open reading frames are essential for the establishment of a successful infection, from efficient replication to long distance movement within the host plant (Castillo *et al*., 2007).

The knowledge of virus-vector relationship is most important in developing appropriate screening test for ToLCV resistance. Mansour and Al-musa (1992) reported that a single whitefly can able to transmit virus with the minimum acquisition and inoculation period of 30 and 60 minutes respectively and latent period was 20-24 hr, the virus was retained by the vector for 11 days.

Disease intensity

Incidence of tomato leaf curl disease occurs throughout the year but the per cent of incidence and intensity vary with the seasons depend upon the climatic condition like temperature, humidity and rainfall and it was highly influenced by the vector population.

Sharma *et al*., 2017 studied the correlation between whitefly population and various abiotic factors and reported that whitefly population has positive correlation with temperature (both maximum and minimum) and sunshine hours. Whereas negative correlation was observed with relative humidity (maximum and minimum) and rainfall. The positive correlation with the temperature can be attributed to the enhanced rate of development and reproduction of whitefly. The relatively higher temperatures can be conducive for rapid multiplication and activity of *B. tabaci*.

Negative correlation with rainfall attributed to the destruction of eggs, nymphs and pupae of whitefly during continuous rains. The time intervals over which rainfall was associated with reduction in *B. tabaci* populations can be interruptive in terms of length of the insect's life cycle. Rains may suppress oviposition, increase the mortality of nymphs, adults and induce insect emigration. Cooler weather, high relative humidity and rainfall can therefore be detrimental to whitefly population and its spread. Hence a strategy should be planned to minimize the pest and disease attack either by manipulation in agronomic practices.

Khandre *et al*., (2019) reported that there is a strong positive correlation between vector population dynamics and per cent disease incidence, in *Rabi* season per cent disease incidence was 25.94 per cent with a white fly population of 2.06/leaf, where as in summer 5.13/leaf with 31.60 per cent disease incidence. Karnataka 90-100 per cent of plant was infected with ToLCD during February to end of May and from July to November per cent of disease incidence is low due to fall in whiteflies population brought about by low temperature (Saikia and Muniyappa, 1989).

Effect of environment factors on tomato leaf curl disease incidence has positive relation with co efficient of infection (%) and climatic factors. Percent of co efficient of infection was maximum in winter compared to rainy season grown crop, this may be due to vector population don't survived and multiplied in summer due to high temperature where as winter season was more favorable for faster multiplication of white fly (Singh *et al.,* 2015).

Crop loss

Crop losses mainly depend on the stage of the plant at which disease infection occurs. In tomato plants early infection causes severe losses and the losses reduced with delay in infection. They were minimum when the plants were infected at the time of maturity. Maximum yield losses of about 98.43 per cent were recorded at 30 days after transplanting , while minimum losses were 5.44 per cent, when it was infected at 75 days after transplanting (Khandre *et al*., 2019).

Genetics and sources of resistance

Due to lack of resistant source in genepool of cutivated species, wild species have been explotied to transfer the resistance into cultivated specises. Tomato leaf curl disease resistance is mainly governed by polygenes, *viz*., *Ty*1, *Ty*2, *Ty*3, *Ty*4 and *Ty*5. These genes are most commonly present in wild species and having different mode of inheritance pattern.

The resistant *Ty*1 gene originated from the *S. chilense* accession LA1969, having inheritance pattern of partial dominance and mapped on the chromosome number 6 (Zamir *et al*., 1994). Dominant resistant gene *Ty*2 originated from the from *S. habrochaites* accession B6013 in the tomato resistant line H24 and mapped on the chromosome number 11 (Hanson *et al*., 2006).

Partial dominant *Ty*-3 resistant gene has been identified in *S. chilense* accessions LA1932, LA1938 and LA2779 and mapped to the long arm of chromosome 6 (Verlaan *et al*., 2013). Since both the *Ty*1 and *Ty*3 genes are present on the same chromosome, these two genes can be easily introgressed in to single genotype. T*y*4 gene with partial dominance present in the *S. chilense* accessions LA1932 was mapped on the long arm of chromosome 3 (Ji *et al*., 2009). Recessive *Ty*5 gene has been identified in the tomato breeding line TY172, which was derived from four different accessions of *S. peruvianum* (PI126926, PI126930, PI390681 and LA0441) and mapped on chromosome 4 (Abinder *et al*., 2009).

New *Solanum pimpinellifolium* accessions INRA, LA1478, PI407543 and PI407544 with different resistance levels were found (Ji *et al*., 2007a) TYLCV resistance derived from *Solanum pimpinellifolium* Hirsute-INRA was shown to be under the control of a single dominant gene. However, its map location is different from that of *Ty* 1. The location of this new gene is between markers TG 153 and CT 83. Along with this gene, there was a QTL located on chromosome 6 accounting for up to 27.7% of the variation in symptom severity (Anbinder *et al*., 2009).. Apart from these wild species *Solanum pimpinellifolium* is one of the most suitable species in tomato breeding, since there is no hybridization barrier in crossing programme with the cultivable species

and fruit size is recovered in few backcrosses (Agnihotri *et al*., 2013).

Breeding for tomato leaf curl diseseae resistance

In order to develop a resistant varieties/hybrids, existing germplasm has to be screened through different screening methods like natural (Hot spot screening), Artificial method (Artificial screening by using whiteflies, Agro inoculation) of screening and use of some of the morphological, physiological and molecular markers to identify the resistant one. Resistant materials are used in the hybridization programme to transfer the disease resistance in to the required material/ cultivated species.

Screening technology

Different screening technologies are used for selecting a resistant genotype based on the symptoms exhibited by plant.

- Hot spot screening.
- Artificial screening by using whiteflies.
- Agroinoculation is a new method of screening.

Hot spot screening

Screening is done in field condition during particular season *i.e.* summer in high disease intensity area. Resistant genotype is selected based on the symptom exhibited by plant.

Artificial screening by using whiteflies

It consists of two methods namely cage and mass inoculation methods.

Cage inoculation

Seedlings were planted in small plastic pots and kept in the glasshouse. Each pot was exposed separately to 15-20 viruliferous whiteflies for 48 h in insect-proof cages covered with insect-proof cotton cloths, with the help of whitefly collectors and transferring tubes. The plants were examined at weekly intervals for expression of ToLCV symptoms and disease incidence for a maximum of 12 weeks. The inoculated plants were maintained in an insect-proof glasshouse at 28±2°C for symptom development. (Singh *et al*., 2015).

Mass inoculation

Seedlings were transplanted into plastic pots filled with soil and compost, kept in a 1.8×1.2×1.5 m (length × breadth × height) insect-proof net chamber (made of silk net). Tomato seedlings from each genotype will be subjected to whiteflies collected from the culture maintained in the glasshouse. The plants need to be examined at weekly intervals for expression of ToLCV symptoms and disease incidence and should be continued up to 60 days after transplanting (Singh *et al*., 2015).

Agro inoculation

In this method of screening, cloned virus particles were mobilized into vector *i.e*. *Agrobacterium tumefaciens* later cultured on Luria Bertani media over night, culture were mixed and used for inoculation, plants of thirty days old seedlings were injected two times in a week by puncturing the plant using needle (Hou *et al*., 1998).

Resistance from the wild species has to be successfully introgressed in to the cultivated species through different conventional and modern breeding method like hybridization, backcross, marker assisted selection and gene pyramiding.

Hybridization

Genetically diverse parents of different wild species has been used in Interspecific hybridization, to identify good combiner for tomato leaf curl disease resistance along with the yield components, based on combining ability and gene action. Singh *et al*., 2014 reported that based on GCA estimates, EC-520061 (*S. habrochaites*), WIR-5032 (*S. chilense*) were good general combiner. Based on the estimates of specific combining ability the hybrids PBC × EC-520061 and PBC × EC-521080 were best specific combiner for coefficient of infection and fruit yield per plant.

Gene pyramiding

Tomato leaf curl disease resistance is governed by polygenes *Viz., Ty1, Ty*2, *Ty3*, *Ty*4 and *Ty*5 combining all the genes in to a single genotype gives stable resistance plant. Level of diseseae resistance varies with the genes with respect to different isolates of viruses. For example *Ty*1 resistance gene carrying line showed level of resistance against some brazalian isolates and bipartite tomato mottle virus (ToMoV) in Florida. *Ty*2 gene carrying lines showed differential responses to TYLCV strains (Ji *et al*., 2007b). In such situation, pyramiding of multiple *Ty* disease resistance genes may improve the spectrum, durability and level of resistance, thereby providing resistance to diverse tomato-infecting begomo viruses. Prasanna *et al*. (2014) reported that Ty3 gene carrying line and pyramided line (*Ty*2+*Ty*3) exhibited high level of resistance to both monopartite (Tomato leaf curl Bangalore virus) and bipartite begomovirus (Tomato leaf curl Palmpur and New Delhi virus). *Ty*2 gene carrying line posses moderate level of resistance to Bangalore virus and sucessptible to both the bipartite viruses. Whereas *Ty*1 gene carrying line showed lower level of resistance to Palmpur virus but posses resistance to Bangalore and New Delhi virus.

Barriers in breeding programme

Linkage drag

Desired resistant gene is tightly linked with the genes of undesirable trait in this condition it is difficult to introgress the gene of interest (Malav *et al*., 2016).

Hybrid sterility

Inter specific hybridization causes embryo abortion.

Unilateral incompatibility

Some wild species like hirsutum posses compatibility only as male parent with cultivated species but as female parent won't set the fruits.

Overcoming of breeding barrier

Embryo rescue

Embryos are manually excised and placed immediately onto a culture medium that provides the proper nutrients to support survival and growth

Eg: *Solanum lycopersicum* × *S.peruvianum* (Kharkongar *et al*., 2013).

Somatic hybridization

Development of hybrid plant through the fusion of somatic protoplast of two different plant species (Wolters *et al*., 1994).

Bridge crosses

In this method highly cross incompatible species is crossed with compatible species the progeny derived from the cross is again crossed with incompatible speciesEg: Progeny derived from the cross *S. peruvianum* × *S.chilense*is crossed with the *S. lycopersicum* (Poysa 1990).

Eg: *S. peruvianum* × *S.chilense*

↓

Progeny × *S. lycopersicum*

CONCLUSION

Identification of new resistant sources, pyramiding of *Ty*1, *Ty*2 and *Ty*3 along with major and minor QTL like *Ty*4, *Ty*5 and *Ty*6 can provide a stable resistance. Use of molecular approaches along with the developmental technology could help to combat the tomato leaf curl virus infection. Identification of new resistant sources and markers for ToLCV resistance will help in the disease management.

Conflict of interest: None.

REFERENCES

Agnihotri, M.K., Gothwal, R.K., Moraniya, N., Singh, R. and Verma, S., (2013). Breeding for resistance to tomato yellow leaf curl virus (TYLCV)/tomato leaf curl virus (ToLCV). Agric. Sustainable Dev. 1(1): 113-117.

Anbinder, I., Reuveni M., Azari R., Paran I., Nahon S., Shlomo H., Chen L., Lapidot, M. and Levin I., (2009). Molecular dissection of *Tomato leaf curl virus* resistance in tomato line TY172 derived from *Solanum peruvianum*. Theoretical and Applied Genetics. 119: 519-530.

Anonymous, (2018). Indian Horticulture Data Base. National Horticulture Board, Ministry of Agriculture.

Capoor, S.P., (1981). Important Virus Diseases of Field and Garden Crops in India and Their Control. ICAR, New Delhi. Pp: 44.

Castillo, A.G., Morilla, G., Lozano, R., Collinet, D., Perez-Luna, A., Kashoggi, A. and Bejarano, E., (2007). Identification of Plant Genes Involved in TYLCV Replication. Tomato Yellow Leaf Curl Virus Disease. Springer. Pp: 207-22.

Chowdareddy, R.V., Colvin, J., Muniyappa, V. and Seal, S., (2005). Diversity and distribution of begamo viruses infecting tomato in India. Arch. Virol. 150: 845-867.

Gronenborn, B., (2007). The tomato yellow leaf curl virus genome and function of its proteins. Tomato Yellow Leaf Curl Virus Disease: 67-84.

Hanson, P. M., Green, S. K. and Kuo, G., (2006). Ty-2, a gene on chromosome 11 conditioning geminivirus resistance in tomato. Tomato Genetics Cooperative Report 56: 17-18.

Hou, Y.M., Paplomatas, E.J., Gilbertson, R.L. (1998). Host adaptation and replication properties of two bipartite geminiviruses and their pseudorecombinants. Mol Plant Microbe Interact. 11: 208-217.

Ji, Y.F., Scott, J.W., Hanson, P., Graham, E. and Maxwell, D.P., (2007a). Sources of Resistance. Inheritance and Location of Genetic Loci Onferring Resistance to Members of the Tomato-infecting Begomoviruses, In: Tomato yellow leaf curl disease. Springer. [Czosnek H (Ed.)], pp: 343-362.

Ji, Y.F., Schuster, D.J. and Scott, J. W., (2007b) *Ty-3*, a begomovirus resistance locus near the tomato yellow leaf curl virus resistance locus *Ty-1* on chromosome 6 of tomato. Mol. Breed. 20: 271- 284

Ji, Y., Scott, J. W.and Schuster, D.J. (2009). Molecular mapping of Ty-4, a new Tomato yellow leaf curl virus resistance locus on chromosome 3 of Tomato. Journal of the American Society for Horticultural Science. 134: 281-288.

Khandare, P.M., Dhutraj, D.N. and Ambadkar, C.V. (2019). Epidemological studies of Tomato leaf curl virus in Marathwada region of Maharastra, India. Int. J. Curr. Microbiol. App. Sci. (11): 688-697.

Kharkongar, H.P., Khanna, V.K., Tyagi, W., Rai, M. and Meetei, N.T. (2013). Wide hybridization and embryo-rescue for crop improvement in solanum. Agrotechnol. 11: 1-6.

Malav, A.K., Indu and Chandrawat, K.S. (2016). Gene pyramiding: An overview. Int. J. Curr. Res. Biosci. Plant Biol. 3(7): 22-28.

Mansour, A. and Al-Musa, A. (1992). Tomato yellow leaf curl virus host range and virus-vector relationships. Plant Path. 41 (2): 122-125.

Mishra, S., Kavi, S.J., Palliath, U.K. and Sagar, P. (2014). Biocontrol of Tomato leaf curl virus (ToLCV) in tomato with chitosan supplemented formulations of Pseudomonas sp. under field conditions. Australian J. Crop Sci. 8(3): 347-355.

Mirza, A., Mehmood, Perveen, R., Chohan, S., Ishtiaq, M., Muhammad, M., Ahmed, Muhammad, Shaaban, M., Younas, A., Umer, H., Akram, N., Abid, M., Sajid, M. (2018). Epidemiological studies of *tomato leaf curl virus* and whitefly population and their management using botanicals Pak. J. Phytopathol. 30 (01): 27-36.

Muniyappa, V., Padmaja, A.S., Venkatesh, H.M., Sharma, A., Chandrashekar, S., Kulkarni, R.S., Hanson, P.M, Chen, J.T., Green, S.K. and Colvin, J. (2002) Tomato leaf curl virus resistant tomato lines TLB111, TLB130 and TLB182. Hort. Science, 37:603-606.

Naresh, J.S. and Nene, Y.N., (1980). Host range,host preference for oviposition an development and the dispersal of Bemisia tabaci Gennadius, a vector of several plant viruses. Indian J. agric. Sci. 50: 620-23.

Pandey, P., Mukhopadhyay, S., Naqvi, A.R., Mukherjee S.K., Shekhawat ,G.S. and Choudhury, N.R., (2010). Molecular characterization of two distinct monopartite begomoviruses infecting tomato in India. Virol. J. 337(7): 1-10.

Poysa, V. (1990). The development of bridge lines for interspecific gene transfer between *Lycopersicon esculentum* and *L peruvianum*. Theoritical and Applied Genetics. 79(2): 187-192.

Prasanna, H.C., Sinha, D.P., Rai, G.K., Krishna, R., Kashyap, S.P., Singh, N.K., Singh, M. and Malathi, V.G. (2014). Pyramiding *Ty2* and *Ty3* genes for resistance to monopartite and bipartite tomato leaf curl virus of India. Plant Patho. 10(1): 1-9.

Ramappa, H.K., Muniyappa, V. and Colvin, J., (1998). The contribution of tomato and alternative host plants to tomato leaf curl virus inoculum pressure in different areas of South India. Ann. Appl. Biol. 133: 187-198.

Raychaudhary, S.P. and Nariani, T.K. (1977). Virus and Mycoplasma Diseases in India. Oxford and IBH Publishing Company, New Delhi. 102 pp.

Saikia, A.K. and Muniyappa, V. (1989). Epidemiology and control of tomato leaf curl virus in southern India. Trop. Agri. 66(4): 350-354.

Saklani, A.U.D. and Mathai, P.J. (1977). Effect of date of planting on leaf curl disease of tomato. Indian Journal of Horticulture. 34: 64-68.

Sastry, K.S.M. and Singh, S.J. (1973). Assessment of losses in tomato by tomato leaf curl virus. Indian J. Myco. Plant Path. 3: 50-54.

Sharma, D., Maqbool, A., Jamwal, V.V.S., Srivastava, K. and Sharma, A. (2017). Seasonal dynamics and management of whitefly (*Bemesia tabaci* Genn.) in tomato (*Solanum esculentum* Mill.). Braz. Arch. Biol. Technol. 60: 1- 8.

Singh, R.K., Rai, N., Singh, M., Singh, S.N. and Srivastava, K. (2014). Genetic analysis to identify good combiners for ToLCV resistance and yield components in tomato using interspecific hybridization. J. Genet. 93: 1-7.

Singh, R.K., Rai. N., Singh. M. and Singh. R. (2015). Effect of climate change on tomato leaf curl virus disease in tomatoes. J. Agric. Sci. 85(2): 142-144.

Singh, R.K., Rai, N., Singh, M., Singh, S.N. and Srivatsva, K. (2015). Selection of tomato genotypes resistant to tomato leaf curl virus disease using biochemical and physiological markers. J. Agric. Sci. 153: 646-655.

Vasudeva, R.S. and Samraj, J. (1948). A leaf curl disease of tomato. Phytopath. 38: 364-369.

Verlaan, M.G., Hutton, S.F., Ibrahem, R.M., Kormelink, R, Visser, R.G.F., Scott, J.W., Edwards, J. D. and Bai, Y. (2013). The tomato yellow leaf curl virus resistance genes Ty-1 and Ty-3 are allelic and code for DFDGD-class RNA-dependent RNA polymerases. PLoS Genetics. 9(3): 1-11.

Wolters, A.M., Jacobsen, E., Connell, M.O., Bonnema, G. and Ramulu, K.S., Jong, H.D. (1994). Somatic hybridization as a tool for tomato breeding. Euphytica. 79(3): 265-277.

Zamir, D. Michelson, I.E., Zakay, Y., Navot, N., Zeidan, M., Sarfatti, M., Eshed, Y., Harel, E., Pleban, T. and Oss, V.H. (1994). Mapping and introgression of a tomato yellow leaf curl virus tolerance gene, Ty-1. Theoretical and Applied Genetics. 88: 141-146.