Chapter 5

Leaf Curl Disease: A Significant Constraint in the Production of Tomato in India

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Additional information is available at the end of the chapter

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Abstract

Tomato (*Lycopersicon esculentum Mill.*) is one of the most economically important vegetable crops in the world. Among the major biotic constraints, virus-associated Tomato leaf curl disease (ToLCD) is a major limiting factor affecting its cultivation and yield. Different symptoms associated with disease are reported such as leaf curling, puckering of leaves, vein yellowing, stunting, excessive branching, from pale yellowing to deep yellowing, and small leaves. The genus *Begomovirus* is a circular single-stranded DNA virus which is exclusively being transmitted by whitefly (*Bemisia tabaci*) in a persistent circulative manner. Most of the begomovirus species are monopartite (having DNA-A molecule only), except few species, which are bipartite (having DNA-A and DNA-B as the genomic component). No absolute effective control measures of the disease could be developed so far, except resistance, management of insect vectors, and altering the dates of sowing to avoid peaks of insect vector population. This chapter reports an account of history, symptoms, transmission, genome organization, distribution, and management of Tomato leaf curl disease.

Keywords: *Begomovirus*, leaf curl, AAP, IAP, betasatellite, DNA-A, DNA-B

1. Introduction

Tomato (*Lycopersicon esculentum Mill.*) is one of the most economically important vegetable crops in the world. The total area of tomato cultivation in the world is 4.582 mha with production of 150.51 MT, and China, India, the USA, Italy, Turkey, and Egypt are major tomato-growing countries in the world.

India is ranked second in area and production after China. The tomato crop covers a total area of 0.879 mha with a production of 18.22 m.t. Andhra Pradesh, Karnataka, Orissa, Maharashtra, West Bengal, Bihar, Gujarat, Chhattisgarh, Tamil Nadu, and Jharkhand are leading states [27].

2. Leaf curl disease

Several biotic and abiotic factors are the major constraints in production of tomato in India. Among the biotic constraints, different viral diseases cause significant impact in tomato production (**Table 1**). Among these viral diseases, tomato leaf curl disease (ToLCD) is devastating and causes significant yield loss under severe conditions. In India, Tomato leaf curl disease (ToLCD) was first reported by Vasudeva in 1948 from Northern India and Sam Raj in 1950 from Central India. The virus can cause infection at any stage of growth and development of plants. Muniyappa et al. [8] reported that yield in summer-planted tomato is less (6.4–52.2%) as compared to winter-planted crops (52.5–100%). Disease incidence, severity, and losses occurred due to this disease depend on the time of infection and is reported to range between 17.6% and 99.7% [1, 2]. Shashti and Singh [3] reported 92.3% loss when infection occurred at 30 days after transplanting. The yield reductions were 94.9, 90.0, 78.0, and 10.8% when plants got infected in 2, 4, 6, and 10 weeks after planting [3]. The disease is caused by different species (**Table 1**) having circular single-stranded DNA (ssDNA), of the

Monopartite and originally reported from tomato				
S. No	Name of the virus species	Acronym	Locality	Year of report
1	*Tomato leaf curl Kerala virus*	ToLKeV	Kerala	2011
2	*Tomato leaf curl Ranchi virus*	ToLCRnV	Ranchi	2011
3	*Tomato leaf curl Patna virus*	ToLCPaV	Patna	2010
4	*Tomato leaf curl Rajasthan virus*	ToLCRV	Rajasthan	2011
5	*Tomato leaf curl Pune virus*	ToLCPuV	Pune	2011
6	*Tomato leaf curl Bangalore virus*	ToLCBV	Bangalore	2000
7	*Tomato leaf curl Karnataka virus*	ToLCKV	Karnataka	2002
8	*Tomato leaf curl Joydebpur virus*	ToLCJoV	Joydebpur	2013
Bipartite and originally reported from tomato				
9	*Tomato leaf curl New Delhi virus*	ToLCNDV	New Delhi	1993
10	*Tomato leaf curl Palampur virus*	ToLCPalV	Palampur	2008
11	*Tomato leaf curl Gujarat virus*	ToLCGV	Gujarat	2003
Monopartite and originally reported from tomato				
12	*Ageratum enation virus*	AEV	Pantnagar	2013
13	*Cotton leaf curl Burewala virus*	CLCBV	Bihar	2013
14	*Tobacco curly shoot virus*	TbCSV	Pantnagar	2013

Table 1. Begomovirus species associated with tomato leaf curl disease in India.

genus *Begomovirus*, family *Geminiviridae* [4, 5]. This chapter summarizes the work carried out on leaf curl of tomato in India.

3. Symptomatology

The symptoms of leaf curl disease are very complex, and the typical symptoms include leaf curling, puckering of leaves, vein yellowing, stunting, excessive branching, from pale yellowing to deep yellowing, and smalling of leaves [6]. Apart from this, it also causes the extreme distortion of leaves, stunting of plants, and premature drop of flower and fruits. Singh and Lal, in 1964, observed that in some genotypes, it causes green vein banding, twisting, and green enation on the under surface of the leaf, upward rolling of margin, and islands of golden colors scattered amidst the normal green tissue [7]. The type of symptom produced is dependent on the genotype cultivated and the developmental stage at which the infection occurs. At cellular level, structural changes have been observed like hypertrophy of nucleus and accumulation of dark granules and the aggregate of virus-like particles in the cytoplasm [8] (**Figure 1**).

Figure 1. Showing leaf curl symptom in tomato crop.

4. Transmission of the virus

Very rich information is available regarding the transmission of the leaf curl viruses of tomato since its discovery. The virus is whitefly transmitted and was demonstrated to occur in several hosts by Vasudeva et al. as early as in 1948. As per the observation of his group, they found

that in winter crop the symptoms appeared 25 days post-inoculation, whereas in summer crop, it took only 15 days. Since the virus characterization was accomplished in the last decade of the twentieth century, it could be presumed that detailed studies on the virus from Southern India may represent the data for monopartite begomovirus mainly ToLCBaV and in Northern India it may include ToLCNDV. The transmission efficiency of the virus depends on the season and the prevailing temperature of the geographical location. Butter et al. [1] reported 100% transmission of virus, the virus with 10 whiteflies/plant at the temperature ranging from 33 to 39°C [1]. Muniyappa et al. [9] described that geographically a different isolate of whitefly behaves differently for acquisition access period (AAP) and inoculation access period (IAP), and he reported minimum 10-min AAP (acquisition access period) and 20-minute IAP (inoculation access period), respectively, for ToLCBaV [9]. It has also recently been reported that ToLCNDV, ToLCGuV, and ToLCKaV are transmissible through sap [10–13]. The begomoviruses causing tomato leaf curl disease have a wide host range affecting various dicotyledonous plants belonging to different families. Host range of the viruses has been determined by graft/whitefly transmission, agroinoculation/biolistic delivery of viral genome into tomato plants, or by detecting the viruses in naturally infected plants using specific primers or probes to virus species.

5. Begomovirus species and its genome organization

The begomoviruses (genus *Begomovirus*, family *Geminiviridae*) constitute the largest group of plant viruses causing devastating crop diseases in India. About 16% of gemini viruses are recorded worldwide occur in India. Currently, 322 begomovirus species have officially been accepted by International Committee on Taxonomy of Viruses (ICTV) from all over the world causing infection in different crops—out of them 82 are reported from India. Among them, around 19 species of begomovirus have been shown to cause leaf curl disease in tomato (**Table 1**). Although the diseases were observed during the mid-twentieth century, the etiology of the disease as a begomovirus was confirmed in the last decade of the twentieth century [14]. Subsequently, based on nucleotide sequence similarity of DNA-A (<89% earlier, and <91% now) genome, different species have been identified. Two species namely *Tomato leaf curl New Delhi virus* and *Tomato leaf curl Palampur virus* predominantly distributed in Northern India and one species namely *Tomato leaf curl Bangalore virus* is dominant in Southern India [9, 14, 15].

The genus *Begomovirus* is a circular single-stranded DNA virus which is exclusively being transmitted by whitefly (*Bemisia tabaci*) in a persistent circulative manner [16]. Most of the begomovirus species are monopartite (having DNA-A molecule only) except few species, which are bipartite (having DNA-A and DNA-B as genomic component). However, in monopartite species, in addition to DNA-A molecule, betasatellite DNA is also present which is almost half of DNA-A component. The DNA-A of both mono- and bipartite species coding for six open reading frames (ORF), two in sense orientation namely AV1 and AV2 and four in complementary orientation namely AC1, AC2, AC3, and AC4, mainly are involved in virus replication and transmission. On the other hand, DNA-B of bipartite species coding for two ORF one in sense orientation namely BV1 and another in complementary orientation namely

BC1 is mainly involved in virus movement within the host [17, 18]. Betasatellite of monopartite species carries only one ORF, which is coded for BC1 protein in complementary sense. ToLCNDV is also found associated with alphasatellites (**Figure 2**).

It has been reported earlier that tomato-infecting begomoviruses have bipartite genome in North India, while monopartite genome in South India [18]. Association of betasatellite DNA molecule with the ToLCD occurring in several places of India was reported [19].

In India, the population of tomato leaf curl viruses is so diverse, and it was shown after coat protein analysis of the 29 infected tomato samples. Based on these analysis, five clusters (with less than 88% similarity among them) were observed among the population, whereas four of them represented the tomato leaf curl viruses. Out of five, one cluster showed 89% similarity with Croton yellow vein mosaic virus [20]. As of now, so many closely related tomato-infecting begomovirus have been cloned and sequenced from India.

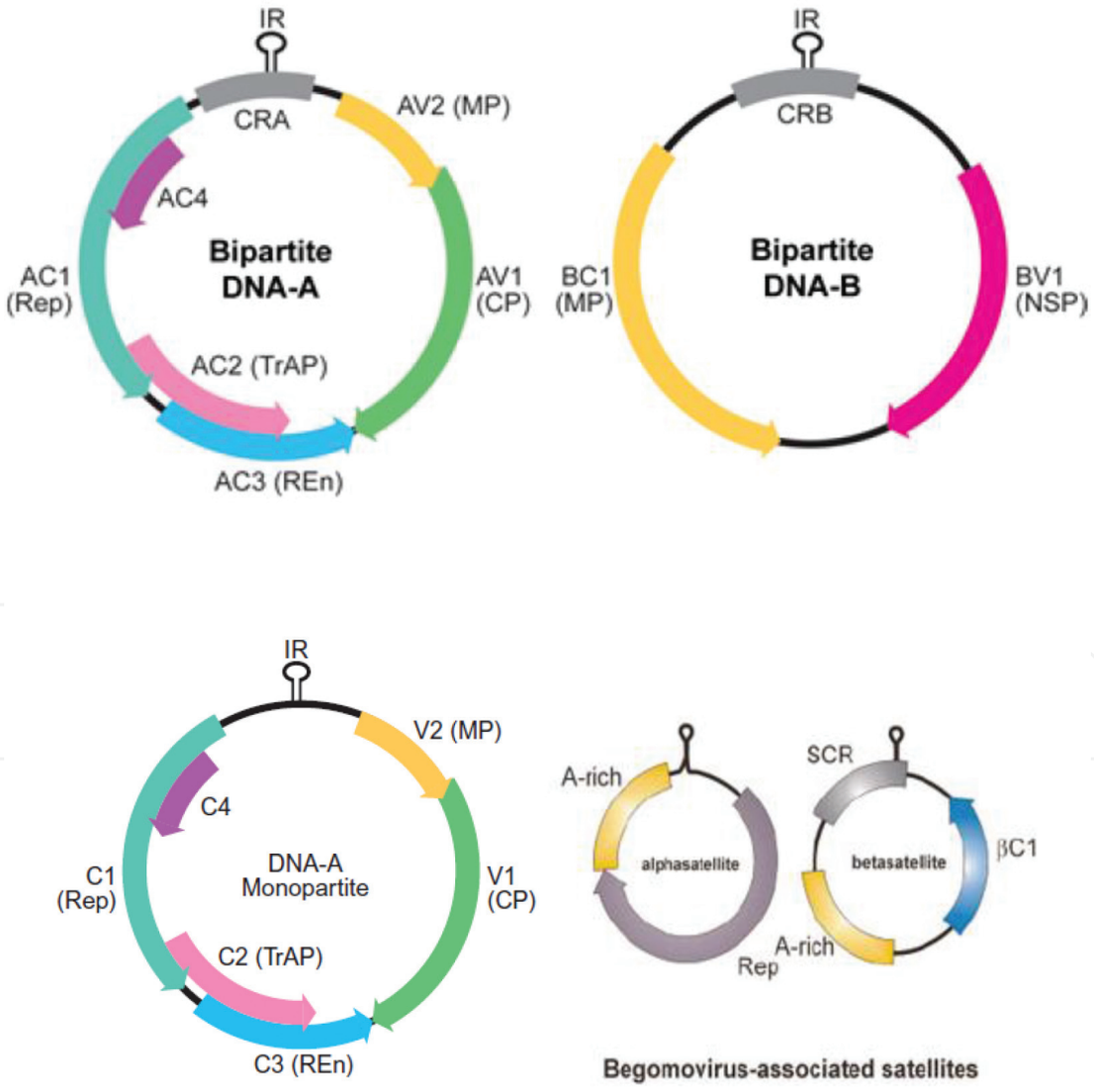

Figure 2. Genome organization of begomovirus associated with leaf curl disease of tomato.

6. Management

Management of viruses is difficult as viruses are systemic in nature, highly variable or diverse, insect vectors, and so on. No effective control measures of the ToLCVs associated with tomato have been developed so far for successful management except resistance, management of insect vectors, and altering the dates of sowing to avoid peaks of insect vector population. Management of ToLCV could be achieved by following various management practices.

a. **Crop rotation** can be utilized for management of disease spread by naturally breaking the life cycles of insect vectors, disease, and weeds. Rotating to nonhost crops prevents the buildup of large populations of the insect vector and also establishes host-free periods.

b. **Introducing a host-free period** may delay infection in tomato by reduced whitefly population due to unavailability of proper host, which ultimately leads to lower rates of virus transmission?

c. Careful monitoring of **sequential plantings** should be done for virus management. Avoid sowing of tomato close to already infected fields. Synchronized planting should be followed to avoid initial inoculum from tomato plants.

d. **The source and use of crop transplants** are also important in reducing or delaying infection. Early infection of susceptible seedlings should be monitored prior to transplanting. Nurseries should produce seedlings for commercial distribution in insect-proof environment or under net cover to minimize infestation by the vector and subsequent virus transmission prior to transplanting. **Roguing**, or immediate removal of infected individual plants, may assist in delaying virus spread once the infected material is immediately destroyed and not left to compost near adjacent, developing fields.

e. Reflective plastic mulches, yellow plastic mulch, and whitefly-proof screens can be employed to reduce the incidence of ToLCV-infected tomatoes.

f. **Biological control**: biopesticides, a mass-produced agent manufactured from a living microorganism or a natural product, may offer a solution to disease control through introduction of predators and parasitoids of the vector. Biopesticides based on microbials such as Beauveria bassiana (effective on nymphs and adults) or Paecilomyces fumosoroseus, Green lacewings, ladybirds, minute pirate bugs, big-eyed bugs, and damsel bugs and Encarsia bimaculata [21] based on microbials such as Beauveria bassiana (effective on nymphs and adults) or Paecilomyces fumosoroseus. Green lacewings, ladybirds, minute pirate bugs, big-eyed bugs, damsel bugs and the parasitoid, Encarsia bimaculata [21]. Encarsia formosa is one of the most efficient and studied bioagents of *B. tabaci*. In a recent study, [27] has shown the biological control of ToLCV in tomato by application of chitosan-supplemented formulations of *Pseudomonas sp.* under field conditions. They also observed the higher levels of phenolics, phenylalanine ammonia lyase, peroxidase, and enhanced chitinase activity in rhizobacteria-treated plants (Mishra et al., 2014).

g. **Host resistance**: resistance approach is an easy, more effective approach for control of viral diseases. Three ToLCV-resistant open-pollinated tomato varieties ("**Sankranthi," "Nandi"**

and "Vaibhav") were developed and released officially in 2003–2004 in India. "Gene pyramiding" is combining multiple Ty genes in tomatoes with resistance to several whitefly-transmitted begomoviruses that cause TYLCVD [28]. Until now, six genes (*Ty* genes) derived from different tomato wild species have been identified. Prasanna et al. [22] attempted to combine *Ty-2* and *Ty-3* genes through marker-assisted selection and screened the hybrid lines for resistance to viruses by challenging through agroinoculation of specific, monopartite, and bipartite viruses and found that the lines and hybrids with *Ty-2* were susceptible to ToLCNDV. The *Ty-3* gene showed dosage effect with partial resistance of plants to ToLCNDV in the heterozygotes stage. By pyramiding *Ty-2* and *Ty-3* genes, considerable resistance to ToLCNDV can be achieved. The resistance of some of the tomato genotypes Vaibav, Nandhini, having *Ty-2* gene to ToLCBaV were lost, when these genotypes were individually agroinoculated with ToLCBaV [13] and the cognate betasatellite.

h. Chemical control: foliar spray of neem (azadairachtin) and neem plus can kill the eggs, nymphs, and adults of *B. tabaci*. Ethanolic and aqueous extracts of *Annona squamosal, Carlowrightia myriantha, Trichillia arborea, Azadirachta indica*, and *Acalypha gaumeri* are effective against *B. tabaci* population. Neem oil, garlic, and eucalyptus extract give significant results against this disease [23]. The chemical control method is easy and most commonly used approach against the insect pest. A number of insecticides are used. Among them, imidacloprid, acetamiprid, nitenpyram, thiamethoxam, and diafenthiuron give significant results against aphids, whiteflies, and other insect pests [24, 25].

7. Conclusion

Begomoviruses are the most important viral pathogens in the Indian subcontinent. Tomato leaf curl disease is one of the devastating diseases and has been reported to be associated with several begomoviruses, thus making breeding for resistance more challenging. Adding to this, presence of diverse betasatellite increases complexity. Climate change and injudicious use of pesticides ensure the persistence of whitefly throughout the year and pose further challenges for the management of the disease. Besides the viral-induced symptom, symptoms caused by sucking of thrips and whitefly confuse the breeder and increase the difficulty for formulating management strategy. A thorough understanding on variability of the virus complexes and understanding the epidemiology could be an alternative in devising management strategy.

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References

[1] Butter NS, Rataul HS. Nature and extent of losses in tomatoes due to tomato leaf curl virus (TLCV) transmitted by whitefly, *Bemisia tabaci* Gen. (Hemiptera, Aleyrodidae). Indian Journal of Ecology. 1981;**8**:299-300

[2] Kalloo G. Leaf curl virus of tomato and chilli in India. In: Proceeding of the phase I final workshop of the South Asian Vegetable Research Network. Kathmandu; January 23–28, (1996): pp 229-234

[3] Sastry KSM, Singh SJ. Assessment of losses in tomato by tomato leaf curl virus. Indian Journal of Mycology and Plant Pathology. 1973;**3**:50-54

[4] Fauquet CM, Briddon RW, Brown JK, Moriones E, Stanley J, Zerbini M, Zhou X. Geminivirus strain demarcation and nomenclature. Archives of Virology. 2008;**153**(4):783-821

[5] Stanley J, Gay MR. Nucleotide sequence of cassava latent virus DNA. Nature. 1983;**301**: 260-262

[6] Vasudeva RS, Sam Raj J. A leaf curl disease of tomato. Phytopathology. 1948;**38**:364-369

[7] Singh DV, Lal SB. Occurrence of viruses of tomato and their probabales strains at Kanpur. Proceedings National Academy Science India. 1964;**34**:179-187

[8] Saikia AK, Muniyappa V. Epidemiology and control of tomato leaf curl virus in Southern India. Tropical Agriculture. 1989;**66**:350-354

[9] Muniyappa V, Venkatesh HM, Ramappa HK, Kulkarni RS, Zeidan M, Tarba CY, Ghanim M, Croznek H. Tomato leaf curl virus from Bangalore (ToLCV-Ban4): Sequence comparison with Indian ToLCV isolates, detection in plants and insects and vector relationships. Archives of Virology. 2000;**145**:1583-1598

[10] Chakraborty S, Pandey PK, Banerjee MK, Kalloo G, Fauguet CM. Tomato leaf curl Gujaratvirus, a new begomovirus species causing a severe leaf curl disease of tomato in Varanasi, India. Phytopathology. 2003;**93**:1485-1495

[11] Chatchawankaphanich O, Maxwell DP. Tomato leaf curl Karnataka virus from Bangalore, India, appears to be a recombinant Begomovirus. Phytopathology. 2002;**12**:637-645

[12] Sohrab SS, Mandal B, Varma A. Characterization of the virus associated with Lufa mosaic disease in northern India. National Symposium on Crop Surveillance: Disease Forecasting and Management. IARI, New Delhi; February 19–21, (2004): 25

[13] Usharani KS, Surendranath B, Paul-Khurana SM, Garg ID, Malathi VG. Potato leaf curl-anew disease of potato in Northern India caused by a strain of tomato leaf curl New Delhi virus. Plant Pathology. 2004;**53**:235

[14] Padidam M, Beachy RN, Fauquet CM. Tomato leaf curl geminivirus from India has a bipartite genome and coat protein is not essential for infectivity. The Journal of General Virology. 1995;**76**:25-35

[15] Kirthi N, Maiya SP, Murthy MRN, Savithri HS. Evidence for recombination among the tomato leaf curl virus strains/species from Bangalore. India. Archives of Virology. 2002; **147**:255-272

[16] Rubinstein G, Czosnek H. Long-term association of tomato yellow leaf curl virus with its whitefly vector Bemisia tabaci: Effect on the insect transmission capacity, longevity and fecundity. Journal of General Virology. 1997;**78**:2683-2689

[17] Rojas MR, Hagen C, Lucas WJ, Gilbertson RL. Exploiting chinks in the plant's armor: Evolution and emergence of geminiviruses. Annual Review of Phytopathology. 2005;**43**: 361-394

[18] Varma A, Malathi VG. Emerging geminivirus problems: A serious threat to crop production. The Annals of Applied Biology. 2003;**142**:145-164

[19] Sivalingam PN, Varma A. Role of betasatellite in the pathogenesis of a bipartite begomovirus affecting tomato in India. Archives of Virology. 2010;**12**:17-22

[20] Chowda Reddy RV, Colvin J, Muniyappa V, Seal S. Diversity and distribution of begomoviruses infecting tomato in India. Archives of Virology. 2005;**150**:845-867

[21] Qian M, Hu Q, Ren S, Mandour NS, Qiu B, Stansly PA. Delayed development of the whitefly (*Bemisia tabaci*) and increased parasitism by *Encarsia bimaculata* in response to sublethal doses of piperonyl butoxide. Insect Science. 2011. DOI: 10.1111/j.1744-7917.2011.01461.x

[22] Prasanna HC, Sinha DP, Rai GK, Krishna R, Kashyap SP, Singh NK, Malathi VG. Pyramiding Ty-2 and Ty-3 genes for resistance to monopartite and bipartite tomato leaf curl viruses of India. Plant Pathology. 2015;**64**(2):256-264

[23] Khan MH, Ahmad N, Rashdi S, Rauf I, Ismail M, Tofique M. Management of sucking complex in bt cotton through the application of different plant products. Pakistan Journal of Life Science. 2013;**1**(01):42-48

[24] Bacci LAL, Crespo TL, Galvan EJ, Pereira MC, Picanço GA, Chediak M. Toxicity of insecticides to the sweetpotato whitefly (Hemiptera: Aleyrodidae) and its natural enemies. Pest Management Science. 2007;**63**(7):699-706

[25] Mandal KA, Praveen KM, Subrata D, Arup C. Effective management of major tomato diseases in the gangetic plains of Eastern India through integrated approach. Agriculture Research & Technology. 2017;**10**(5):555796. DOI: 10.19080/ARTOAJ.2017.10.555796

[26] Mishra S, Jagadeesh KS, Krishnaraj PU, Prem S. Biocontrol of tomato leaf curl virus (ToLCV) in tomato with chitosan supplemented formulations of Pseudomonas sp. under field conditions. Australian Journal of Crop Science. 2014;**8**(3):347-355

[27] National horticulture database. 2013

[28] http://avrdc.org/seed/improved-lines/

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