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Viral Threats to Tomato Production: Symptoms and Sustainable Management Strategies

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Tomato (*Solanum lycopersicum* L.) is an economically important vegetable crop; however, its productivity and fruit quality are constrained by viral diseases. Important viruses affecting tomato include Tomato mosaic virus (ToMV), viruses associated with tomato leaf curl disease, Cucumber mosaic virus (CMV), Tomato spotted wilt virus (TSWV) and Tomato leaf curl New Delhi virus (ToLCNDV). Infected plants may exhibit leaf curling, mosaic mottling, chlorosis, leaf distortion, bronzing, stunted growth and fruit deformation, resulting in yield and economic losses. Depending on the virus, transmission may occur through insect vectors, contaminated seed or planting material, or mechanical contact. Because curative treatments are generally unavailable once systemic viral infection is established, management relies mainly on prevention and integrated disease-management practices. These include using healthy planting material, raising seedlings in insect-proof nurseries, growing resistant or tolerant cultivars where available, removing infected plants and weed hosts, maintaining field hygiene, and managing insect vectors through locally recommended integrated pest-management practices. Accurate diagnosis matters because symptoms from different viruses can overlap. Serological methods, including enzyme-linked immunosorbent assay (ELISA), and virus-specific molecular methods support reliable identification. For molecular diagnosis, PCR is used for DNA viruses, whereas RNA viruses generally require reverse-transcription PCR (RT-PCR) or another validated RNA-detection method. Integrating early detection, diagnosis, sanitation and vector management can help reduce virus spread and support sustainable tomato production.

Keywords: *Solanum lycopersicum*, tomato viruses, ToMV, tomato leaf curl disease, CMV, TSWV, ToLCNDV, integrated disease management, vector management, diagnosis.

Introduction

Tomato (*Solanum lycopersicum* L.) is an important vegetable crop worldwide, contributing to human nutrition and agricultural livelihoods. Production is affected by several viral diseases that can reduce yield, fruit quality and market value. Important viruses and virus-associated diseases of tomato include tomato mosaic, tomato leaf curl disease, cucumber mosaic, tomato spotted wilt and tomato leaf curl New Delhi disease. The occurrence and severity of these diseases vary with the virus involved, the tomato cultivar, environmental conditions and the presence of vectors or alternative host plants. Symptoms may include leaf curling, yellowing, mosaic patterns, leaf distortion, bronzing, stunting and deformed fruit. Because these symptoms are not always unique to a particular virus, visual assessment alone may be insufficient for definitive diagnosis. Depending on the virus, spread may occur through whiteflies, aphids or thrips, through contaminated seed or planting material, or by mechanical transmission. Preventive management therefore combines healthy planting material, resistant or tolerant cultivars where available, field sanitation, removal of infected plants and appropriate

vector management. The 2026 study by Kazemi *et al*. concerns tomato leaf curl Palampur virus and priming treatments; it should not be used as general evidence for all tomato viruses.

Major Viral Diseases of Tomato

1. Tomato mosaic disease – Tomato mosaic virus (ToMV): Tomato mosaic virus (ToMV), a member of the genus Tobamovirus, is highly stable and is transmitted mainly through mechanical contact and contaminated plant material. Symptoms may include light- and dark-green mosaic mottling, leaf distortion, reduced or narrow leaves, stunting and, in some cases, necrotic symptoms on stems or fruit. The virus can spread during transplant handling and routine crop operations when contaminated hands, tools or equipment contact susceptible plants. Seed-associated contamination can also contribute to the introduction of the virus. Management focuses on prevention because curative treatment is not available for plants with established systemic infection. Use seed and seedlings from reliable sources, remove and destroy infected plants, clean and disinfect tools and equipment using an appropriate method, and maintain hand hygiene during crop handling. Resistant cultivars should be used where suitable and locally recommended. Any seed-treatment protocol, including chemical or heat treatment, should be followed only when supported by a validated recommendation for the cultivar and seed lot.

2. Tomato leaf curl disease: Tomato leaf curl disease is associated with several Begomoviruses in the family Geminiviridae. These viruses are transmitted primarily by the whitefly *Bemisia tabaci* in a persistent manner. Symptoms may include upward or downward leaf curling, leaf-margin rolling, yellowing, reduced leaf size, thickened veins, crinkled young foliage, shortened internodes and stunted or bushy growth. Flowering and fruit set may also be reduced, leading to substantial yield loss. Management should emphasize prevention and integrated whitefly management. Raise seedlings under insect-proof netting, use healthy transplants, monitor whitefly populations with yellow sticky traps, remove infected plants early where appropriate, and control weed hosts and volunteer tomato plants that may act as virus reservoirs. Use locally recommended integrated pest-management practices and cultivars with documented resistance or tolerance where available.

Fig. 1. Symptomatic Tomato Plant Affected by Leaf Curl Disease

3. Cucumber mosaic disease – Cucumber mosaic virus (CMV): Cucumber mosaic virus (CMV) may cause light- and dark-green mosaic patterns, leaf mottling, chlorosis, puckered foliage and stunted growth in tomato. In some infections, leaves become narrow and elongated, producing a shoestring- or fern-leaf appearance. CMV is transmitted by several aphid species in a non-persistent manner, so transmission can occur rapidly during probing. Consequently, insecticide use alone may not reliably prevent virus transmission. Management includes planting healthy seedlings, removing infected plants where practical, controlling weed hosts and maintaining field sanitation. Use resistant or tolerant cultivars where available. Reflective mulches may help reduce aphid landings in suitable production systems, but their effectiveness depends on local conditions. Avoid establishing new tomato crops close to infected host crops where feasible.

4. Tomato spotted wilt disease – Tomato spotted wilt virus (TSWV): Tomato spotted wilt virus (TSWV) can cause stunting, chlorotic or necrotic rings on leaves, bronzing of young foliage, thickened veins, necrotic streaks on stems and dieback of growing tips. Infected plants may show uneven growth or wilt-like symptoms. Fruits may develop pale or yellow areas and characteristic concentric rings. Symptom expression varies with the cultivar, plant age and virus isolate (Aravintharaj *et al.,* 2023). TSWV is transmitted by certain thrips species. Thrips generally acquire the virus during their larval stages and can transmit it later as adults. Management includes monitoring thrips, removing infected plants and relevant weed hosts, and implementing locally recommended integrated pest-management practices. Insecticides, if required, should be registered for the intended use and applied according to label directions.

Barrier crops or plant extracts should be recommended only when reliable evidence demonstrates their effectiveness under the relevant conditions.

5. Tomato leaf curl New Delhi disease - Tomato leaf curl New Delhi virus (ToLCNDV): Tomato leaf curl New Delhi virus (ToLCNDV) is a bipartite, single-stranded DNA virus belonging to the genus Begomovirus in the family Geminiviridae. Its genome comprises DNA-A and DNA-B components. The virus infects several crop species, particularly members of the families Solanaceae and Cucurbitaceae, and is transmitted primarily by *Bemisia tabaci* in a persistent manner. In tomato, symptoms may include leaf curling, yellowing, chlorotic patches, vein thickening, shortened internodes, stunted growth and fruit deformation. Infected plants, volunteer crops and weed hosts may contribute to virus persistence and spread. Hu *et al*. (2025) describe a multiplex PCR assay for the simultaneous detection of tomato yellow leaf curl virus and ToLCNDV. Management includes raising healthy seedlings under insect-proof netting, monitoring whiteflies, removing infected plants and weed hosts where appropriate, maintaining field sanitation, and adopting integrated vector-management practices. Resistant or tolerant varieties should be used where they are available and recommended for local production area.

Fig. 2. Characteristic symptoms of Tomato leaf curl New Delhi virus (ToLCNDV) in tomato:
(**A**) Leaf mottling and deformation (**B**) Leaf curling, yellowing and mosaic symptoms.

An Integrated Approach to Managing Tomato Viral Diseases

Because effective curative treatments are generally unavailable after systemic viral infection is established, prevention and integrated management are essential. Use healthy seeds and disease-free seedlings from reliable sources, raise seedlings in insect-proof nurseries, and select resistant or tolerant cultivars wherever suitable. Inspect crops regularly and remove suspected infected plants when recommended for the disease and production system. Manage weed hosts and volunteer crops that may serve as virus reservoirs. Monitor whiteflies, aphids and thrips and apply integrated pest-management practices appropriate to the vector and virus involved. Yellow sticky traps can support monitoring of whiteflies and other flying insects, while blue traps may be useful for thrips monitoring in some systems; traps should not be treated as a stand-alone control method. Reflective mulches and biological control may be useful in suitable settings. If insecticides are needed, use products registered for the crop and target pest and follow label directions. Clean tools and equipment and maintain hand hygiene to reduce mechanical spread of viruses such as ToMV. Maintain nursery hygiene, avoid unnecessary movement of workers through infected crops, and reduce overlapping susceptible crops where feasible.

Accurate Diagnosis: The First Step Towards Effective Management

Accurate identification is important because tomato viruses can cause similar symptoms, including leaf curling, mosaic mottling, yellowing, stunting and fruit deformation. Therefore, treat visual symptoms as preliminary evidence rather than definitive confirmation. ELISA may be used for viruses for which suitable validated antibodies are available. Molecular tests should be selected according to the type of viral genome and the validated assay: PCR is commonly used for DNA viruses such as Begomoviruses, whereas RNA viruses such as ToMV, CMV and TSWV generally require RT-PCR or another validated RNA-virus detection method. Early diagnosis supports informed decisions about plant removal, vector management, cultivar selection and other preventive measures.

Conclusion

Viral diseases are an important constraint to tomato production because they can reduce crop productivity, fruit quality and economic returns. Management of ToMV, tomato leaf curl disease, CMV, TSWV and ToLCNDV depends on prevention, timely detection and disease-specific integrated management. Healthy planting material, resistant or tolerant cultivars where available, removal of infected plants and weed hosts, field sanitation, vector monitoring and appropriate vector management are key components. Laboratory diagnosis is valuable when symptoms overlap or a definitive identification is required. Combining these practices with regular crop monitoring and farmer awareness can help reduce virus spread and support sustainable tomato production.

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