Medical and Life Sciences (2025) 4(2): 48–54
ISSN (E): 2976-7245

Aphis gossypii transmitted Citrus Tristeza Virus: A Major Threat to Production of Citrus with Emphasis

Sonum Bashir[1]
Muhammad Asif Shabbir[1]
Muhammad Awais Fareed[1]
Faheema Bakhtawar[2]
Rida Fatima[3]
Sadia Basheer[4]
Iram Bilqees[1]
Muhammad Tayyab Mateen[5]
Humera Aslam[6]

How to cite this article:

Bashir, S., Shabbir, M. A., Fareed, M. A., Bakhtawar, F., Fatima, R., Basheer, S., Bilqees, I., Mateen, M. T., & Aslam, H. (2025). Aphis gossypii transmitted Citrus tristeza virus: A major threat to production of citrus with emphasis. *Medical and Life Sciences, 4*(2), 48–54.

Received: 15 July 2025 / Accepted: 15 November 2025 / Published online: 30 December 2025

Abstract

Citrus is an important world fruit crop in Pakistan due to both its nutritional value and economic importance. This can be cultivated in tropical and subtropical areas with production exceeding 100 million tonnes annually. Pakistan ranks among the topmost contributors with respect to production of different citrus crops especially Kinnow mandarins but its productivity is limited because of various biotic stresses. Of these, viral diseases represent the key threat and Citrus tristeza virus (CTV) is considered as most damaging pathogens to citrus orchards worldwide. It is a phloem-limited, ssRNA virus causing a broad spectrum of symptoms. The major symptoms of CTV include stem pitting, stunting, decline and fruit quality reduction. *Aphis gossypii* transmits this virus mainly from infected planting material to healthy plants while infected plant material is also an important source. Citrus trees infected suffer for life, often resulting in dramatic yield reductions and reduced production longevity. CTV has been reported from major citrus growing areas in Pakistan and its incidence has increased overtime, especially in Punjab. This review emphasizes the global significance of citrus, current status on Citrus production in Pakistan and biological and epidemiological aspects of Citrus tristeza virus. This review also emphasizes on the need for better management practices and more studies to ascertain the spread and severity of CTV under local ecological environments. Overcoming this challenge is critical for the continued production of citrus and for the agricultural economy.

Keywords: Citrus, Citrus tristeza virus, CTV, Pakistan, citrus production, viral diseases, aphid

[1]Department of Plant Pathology, College of Agriculture, University of Sargodha, Sargodha-40100, Pakistan.
Corresponding Author: sonumbashir@gmail.com
[2]Pest Warning & Quality Control of Pesticides, Sargodha, 40100, Pakistan
[3]Food and Agriculture Organization of United Nation, Khanewal-58150, Pakistan
[4]Department of Plant Pathology, University of Agriculture, Faisalabad, Pakistan
[5]Centre of Excellence for Citrus, College of Agriculture, University of Sargodha, Sargodha-40100, Pakistan.
[6]Department of Environmental Sciences, COMSATS University Islamabad, Vehari Campus, Vehari-61100, Pakistan

transmission, plant pathology

1. Introduction / Global Citrus Importance

Citrus are major fruit trees, from household gardens to industrial orchards worldwide. The origin of Citrus is thought to be Southeast Asia, with *C. maxima* (grandis), *C. medica*, *C. reticulata* and *C. balimii* being considered as its original forms (Dugo & Giacomo 2004). The world citrus production in 2019 was 143.76 million tonnes and the top producing countries were China, Brazil, and the United States (FAO, 2020). Citrus fruits are popular for their high nutritional value because they contain sugars such as glucose, sucrose, fructose including vitamin A, B and C, dietary fiber and also other bioactive compounds (Liu et al., 2012) that have beneficial attributes. Moreover, there are various reports that the waste obtained from citrus processing can be utilized for biofuel production (Mahato, 2021).

2. Pakistan Citrus Production Context

Pakistan ranks the 13th position in the world list of top 15 citrus-producing countries (FAO, 2013). About 200,000 hectares are utilized for citrus cultivation in Pakistan. The produce of Citrus was over two million tons yearly mainly located in Punjab and Khyber Pakhtunkhwa provinces. Mandarin is the main cultivar in Punjab, and sweet oranges are more prevalent in KP. Mandarins are the major cultivar of Punjab but sweet oranges are more common in KP. Citrus crops are commonly susceptible to diverse viruses and virus-like diseases (Iqbal et al., 2015; Naqvi et al., 2015) which can cause serious economic losses for many of the growers with CTV recognized as the most threatening virus in citrus pathogenicity (Naseem et al., 2016).

Pakistan is the at sixth rank as largest producer of Kinnow globally. However, despite this, it ranks relatively low among citrus-producing countries in terms of overall citrus fruit production (Mubeen et al., 2024). Citrus trees in Pakistan face significant losses due to a range of diseases caused by bacteria, fungi and phytoplasmas etc. (Iftikhar et al., 2024; Mubeen et al., 2015). In tropical and subtropical areas, citrus is considered the most important fruit crop (Arif et al., 2005). Pakistan is one of the top ten most promising citrus-producing countries in the world due to the high quality and quantity of its oranges (Chohan et al., 2007). In Pakistan, citrus is grown on 0.198 million hectares, producing about 2.47 million tons a year (FAO, 2020). However, since the 1920s, a variety of diseases, including fungi, bacteria, viruses, and virus-like agents, have been known to negatively impact orange production in Pakistan, much like they do for other important crops (Arif et al., 2005; Naseem et al., 2016). Among the most serious constraints to citrus production are viral and virus-like diseases (Yaqub et al., 2017; Fateh et al., 2017). Particularly Citrus tristeza virus (CTV), one of the most damaging viruses reported in the country (Chohan et al., 2007).

3. CTV Importance and Disease Burden

Once a citrus tree is infected with the virus, there is no possible solution for the management of the diseases and trees will ultimately die. CTV degenerates the cambium layers of citrus trees, causing the progressive decline in plants (Shafique et al., 2024). Like other cultivated crops, citrus is vulnerable to a wide range of pests and diseases that negatively impact its growth, yield, and overall productivity. Among the key contributors to citrus decline is Citrus tristeza virus (CTV), a well- documented and highly destructive pathogen (Alhawat and Pant, 2003). CTV-related epidemics and their role in the deterioration of citrus orchards have been reported in numerous countries, including Brazil, Argentina, California, Venezuela, Spain, Israel, Cuba, Mexico, the Dominican Republic, Florida, and others (Moreno et al., 2007; Atta et al., 2012), where the virus has led to the death of millions of citrus trees (Sharma, 2023).

Citrus tristeza virus (CTV) is the most destructive viral infection that affects citrus crops. More than 100 million trees have been lost as a result of catastrophic epidemics brought on by CTV in citrus-producing regions worldwide during the past century. Citrus cultivation is still seriously threatened by the virus in many nations (Folimonova et al., 2022).

4. Transmission and Spread

CTV, a member of the family *Closteroviridae* and genus *Closterovirus*, is primarily spread by insect vectors such as mealybugs, aphids, and whiteflies (Karasev et al., 1997). The aphid Aphis gossypii is the most efficient vector, capable of transmitting multiple CTV strains between plants and orchards (Roistacher & Moreno, 1991).

More than 30 viruses and virus-like diseases are known to affect citrus crops worldwide, with Citrus tristeza virus (CTV) considered the most destructive among them (Atta et al., 2012). The global spread of CTV has primarily occurred through the movement and propagation of infected plant material, particularly industrial plants and budwood, as well as by certain aphid species (Cárdenas et al., 2002; Afechtal, 2013; Haq & Naz, 2018).

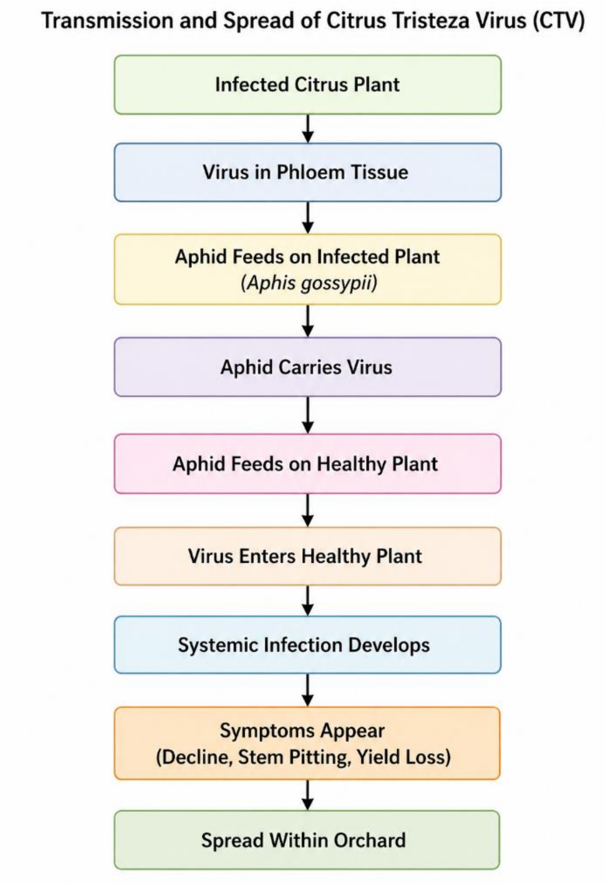

Figure 1: Schematic representation of transmission and spread of Citrus tristeza virus (CTV) through aphid vectors and infected plant material in citrus orchards.

5. Symptoms and Disease Expression

Key symptoms include stem pitting, which disrupts vascular development, and tree decline, which can lead to the death of the plant (Karasev et al., 1997; Roistacher & Moreno, 1991). When a certain strain of CTV attacks a tree, the infected tree may develop symptoms (Vives et al., 1999). The virus induces various symptoms including slow and quick decline, stunting, stem pitting, vein clearing, and seedling yellows (Atta et al., 2017).

Citrus tristeza virus (CTV), the primary cause of the most significant viral disease in citrus, leads to rapid decline in most citrus species grafted onto sour orange rootstock. In addition, CTV infection can cause stem pitting, stunted growth, and reduced fruit yield and quality in certain scion cultivars, regardless of the rootstock used (Bar-Joseph et al., 1989; Domínguez et al., 2002; Muniz et al., 2012). Citrus tristeza virus (CTV) infections in Citrus species primarily result in two major diseases: (i) quick decline (QD) of many scion varieties grafted onto sour orange rootstock, and

(ii) stem pitting (SP), which affects grapefruit, pummelo, and certain orange varieties. A third condition, seedling yellows seen in young sour orange, lemon, and grapefruit plants is generally observed only under controlled experimental conditions (Bar-Joseph et al., 1989).

Table 1: Key characteristics of Citrus tristeza virus (CTV) and its impact on citrus production

Parameter	Description
Virus Name	Citrus tristeza virus (CTV)
Virus Type	Positive-sense single-stranded RNA (ssRNA)
Family / Genus	Closteroviridae / Closterovirus
Genome Size	~20 kb
Primary Vector	Aphid (*Aphis gossypii*)
Mode of Transmission	Aphid transmission and infected planting material
Host Range	Citrus species and closely related plants
Major Symptoms	Stem pitting, decline, stunting, vein clearing, seedling yellows
Disease Impact	Reduced yield, poor fruit quality, tree death
Status in Pakistan	Widely reported; high incidence in Punjab regions
Management Strategies	Certified planting material, vector control, monitoring, research

6. Molecular Characteristics and Structure

Citrus tristeza virus (CTV) possesses a relatively large genome of about 20 kilobases, consisting of a positive-sense single-stranded RNA molecule with untranslated regions at both ends. This genome is organized into 12 open reading frames, which play important roles in viral replication and function (Karasev et al., 1997; Moreno et al., 2008). The virus is classified within the family Closteroviridae, under the genus Closterovirus, based on its structural, biological, and molecular characteristics.

Structurally, CTV particles are long, flexible, and thread-like, typically measuring around 2,000 nm in length and approximately 11-12 nm in diameter. These filamentous virions are non-enveloped and confined to the phloem tissue of infected plants. The viral genome is enclosed by two coat proteins, forming a distinctive polar structure. A major coat protein, weighing about 25 kDa, covers most of the viral particle, while a smaller 27kDa minor coat protein is located at one end, giving the virion a characteristic “rattlesnake-like” appearance (Abbas et al., 2013).

In addition, the genome includes essential untranslated regions at both the 5′ and 3′ ends, which, along with ORFs 1a and 1b, are crucial for replication processes. Overall, the combination of its large RNA genome, unique structural organization, and phloem-restricted nature makes CTV one of the most complex plant viruses studied to date (Satyanarayana et al., 2004; Naseem et al., 2016; Gaur et al., 2023).

7. Epidemiology and Spread

Citrus tristeza virus (CTV) was first reported in Pakistan in the late 1980s during a survey of citrus orchards in the Khyber Pakhtunkhwa (KPK) and Punjab regions. Its presence was confirmed using ELISA and electron microscopy techniques (Lin et al., 2006). Subsequent surveys conducted in 2006-2007 also detected CTV in various locations across Punjab and KPK (Abbas et al., 2008; Iftikhar et al., 2009). The highest infection rate recorded during that period was 48% in Bhalwal (Punjab) and 40 % in Mardan (KPK) (Iftikhar et al., 2009). Later, in 2013, CTV incidence increased to 67% in Sargodha and remained at 39 % in Mardan (Naseem et al., 2016). Despite these findings, few studies have been conducted on the spatio-temporal dynamics of CTV in Sargodha, a region often referred to as the "California of Pakistan" due to its significant citrus production (Khan et al., 2022).

In Pakistan, citrus trees often have a shortened productive lifespan, leading to reduced yields and a decline in fruit quality. The first reports of viral diseases in Pakistan described widespread dieback and decline in citrus trees, although the exact cause was unclear at the time. Subsequent surveys across various citrus-growing regions confirmed the presence of multiple viral and virus-like diseases (Catara et al., 1988). It was later confirmed the presence of Citrus tristeza virus (CTV) in citrus trees through field surveys and diagnostic testing using enzyme-linked immunosorbent assay (ELISA) (Abbas et al., 2008).

8. Advanced Research and Molecular Studies

Citrus tristeza virus (CTV) is among the most biologically advanced plant viruses and belongs to the family of *Closteroviridae*. Citrus virus is the most virulent virus found in citrus plants when it comes to economics. CTVs that are responsible for a disease known as "tristeza" have caused epidemics in North and South America, as well as the Mediterranean region, leading to the death of millions of trees in the last one hundred years. Even today, Citrus tristeza virus (CTV) remains a major concern for citrus production worldwide. Its impact is far from controlled, and it continues to threaten orchard sustainability in many regions. From a scientific standpoint, studying this virus is particularly challenging. This is largely due to its unusually large RNA genome and the delicate, thread-like nature of its viral particles, which complicate experimental handling. In addition, CTV has a very narrow host range, primarily infecting slow-growing Citrus species. Within these plants, the virus specifically targets phloem-associated cells, making its behavior more complex to observe and understand (Folimonova et al., 2020). IDM on management of CTV diseases can include the impact of changing climate on the citrus production and Artificial intelligence or latest crop monitoring systems to avoid the disease.

CTV is a phloem-restricted, insect-transmissible virus that appears to be able to naturally infect only citrus and very closely related species. They have killed millions of trees, obliterated entire citrus industries and continued to restrict citrus production in a number of regions although most CTV isolates are benign or asymptomatic on large areas of their host range. It is still unclear what mechanisms lead CTV to produce severe illness in some citrus species but not in others. Unlike well-studied viruses of herbaceous plants, which typically move between adjacent cells, CTV primarily spreads systemically through long-distance transport, with minimal cell-to-cell movement. It moves through the sieve elements, and can also infect nearby companion or phloem parenchyma cells where it replicates (Dawson et al., 2013).

Conclusion

The Florida T36 isolate of CTV was the first to be fully sequenced [4] (published in 1995), although parts of the 3' end and coat protein gene had been previously reported. These sequencing efforts uncovered two major findings: First, there is substantial genetic divergence in the 5' regions of the genomes of T36 and several isolates of VT (highly virulent strains), and second, many CTV isolates contain multiple defective RNAs.

Author Contributions

Sonum Bashir, Muhammad Asif Shabbir, Muhammad Awais Fareed, Faheema Bakhtawar, Rida Fatima, Sadia Basheer, Iram Bilqees, Muhammad Tayyab Mateen, and Humera Aslam contributed to the conceptualization, literature search, review of citrus pathology and virus-transmission evidence, synthesis and interpretation of the relevant literature, organization of the scientific content, and preparation of the manuscript. All authors contributed to writing—original draft and writing—review and editing. All authors read and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

Conflict of Interest

The authors declare that they have no financial, professional, commercial, institutional, or personal conflicts of interest that could have influenced the content or conclusions of this article.

Funding

This research received no specific grant from any funding agency in the public, commercial, or

not-for-profit sectors.

Data Availability

No new experimental, laboratory, or field dataset was generated or analysed for this study. All information supporting the review was obtained from the published scientific literature and publicly accessible sources cited in the manuscript.

Informed Consent

Not applicable. The study did not involve human participants or the collection of personal information.

Use of Generative AI

The authors declare that no generative artificial intelligence tools were used to conduct the literature analysis, generate the scientific content, interpret the evidence, or formulate the conclusions presented in this article.

9. References

Abbas, M., Khan, M. M., Fatima, B., Iftikhar, Y., Mughal, S. M., Jaskani, M. J., & Abbas, H. (2008). Elimination of *Citrus tristeza closterovirus* (CTV) and production of certified citrus plants through shoot-tip micrografting. *Pakistan Journal of Botany, 40*(3), 1301–1312.

Abbas, M., Khan, M. M., Mughal, S. M., & Ji, P. (2013). Characterization and assessment of seasonal variation of *Citrus tristeza closterovirus* (CTV) in citrus in Pakistan. *Journal of Food, Agriculture & Environment, 11*(3–4), 1063–1068.

Afechtal, M. (2013). *Characterization of Moroccan Citrus tristeza virus (CTV) isolates and study of their genomic variability after aphid transmission* (Doctoral dissertation, University of Catania).

Alhawat, Y. S., & Pant, R. P. (2003). Major virus and virus-like diseases of citrus in India, their diagnosis and management. *Annual Review of Plant Pathology, 2*.

Arif, M., Ahmed, A., Ibrahim, M., & Hassan, S. (2005). Occurrence and distribution of virus and virus-like diseases of citrus in North-West Frontier Province of Pakistan. *Pakistan Journal of Botany, 37*, 407–421.

Atta, S., Siddiq, M., Ashiq, S., & Hannan, A. (2017). Citrus tristeza virus in Pakistan: A review. *Pakistan Journal of Phytopathology, 29*(2), 273–279. https://doi.org/10.33866/phytopathol.029.02.0355

Atta, S., Zhou, C. Y., Yan, Z., Cao, M. J., & Wang, X. F. (2012). Distribution and research advances of *Citrus tristeza virus*. *Journal of Integrative Agriculture, 11*(3), 346–358. https://doi.org/10.1016/S2095-3119(12)60019-7

Bar-Joseph, M., Marcus, R., & Lee, R. F. (1989). The continuous challenge of citrus tristeza virus control. *Annual Review of Phytopathology, 27*, 291–316. https://doi.org/10.1146/annurev.py.27.090189.001451

Cárdenas, M. M. I., León, I. H. A., & Manjunath, K. (2002). Molecular cloning and expression of the p25 gene of two Mexican isolates of *Citrus tristeza virus*. *Revista Mexicana de Fitopatología, 20*, 174–181.

Catara, A., Azzaro, A., Mughal, S. M., & Khan, D. A. (1988). Virus, viroid and prokaryotic diseases of citrus in Pakistan. In *Proceedings of the International Organization of Citrus Virologists* (pp. 957–962).

Chohan, S. N., Qamar, R., Sadiq, I., Azam, M., & Holford, P. (2007). Molecular evidence for the presence of huanglongbing in Pakistan. *Australasian Plant Disease Notes, 2*, 37–38. https://doi.org/10.1071/DN07019

Dawson, W. O., Garnsey, S. M., Tatineni, S., Folimonova, S. Y., Harper, S. J., & Gowda, S. (2013). *Citrus tristeza virus*–host interactions. *Frontiers in Microbiology, 4*, Article 88. https://doi.org/10.3389/fmicb.2013.00088

Domínguez, A., de Mendoza, A. H., Guerri, J., Cambra, M., Navarro, L., Moreno, P., & Peña, L.

(2002). Pathogen-derived resistance to *Citrus tristeza virus* (CTV) in transgenic Mexican lime plants expressing its p25 coat protein gene. *Molecular Breeding, 10*, 1–10. https://doi.org/10.1023/A:1020347415333

Dugo, G., & Di Giacomo, A. (2004). *Citrus: The genus Citrus*. Taylor & Francis.

FAO. (2013). *FAO production yearbook*. Food and Agriculture Organization.

FAO. (2020). *Citrus fruit fresh and processed statistical bulletin 2020*. https://www.fao.org/3/cb6492en/cb6492en.pdf

Fateh, F. S., Mukhtar, T., Kazmi, M. R., Abbassi, N. A., & Arif, A. M. (2017). Prevalence of citrus decline in District Sargodha. *Pakistan Journal of Agricultural Sciences, 54*, 9–13. https://doi.org/10.21162/PAKJAS/17.5643

Folimonova, S. Y. (2020). *Citrus tristeza virus*: A large RNA virus with complex biology turned into a valuable tool for crop protection. *PLoS Pathogens, 16*(4), Article e1008416. https://doi.org/10.1371/journal.ppat.1008416

Folimonova, S. Y., & Sun, Y. D. (2022). *Citrus tristeza virus*: From pathogen to panacea. *Annual Review of Virology, 9*(1), 417–435. https://doi.org/10.1146/annurev-virology-100520-114412

Gaur, R. K., Patil, B. L., & Selvarajan, R. (2023). *Plant RNA viruses: Molecular pathogenesis and management*. Elsevier.

Haq, R., & Naz, S. (2018). Molecular identification and characterization of *Citrus tristeza virus* coat protein from the Punjab Province of Pakistan. *Journal of Animal & Plant Sciences, 28*(3).

Iftikhar, Y., Khan, M. A., Rashid, A., Mughal, S. M., Iqbal, Z., Batool, A., Abbas, M., Khan, M. M., Muhammad, S., & Jaskani, M. (2009). Occurrence and distribution of *Citrus tristeza closterovirus* in the Punjab and NWFP. *Pakistan Journal of Botany, 41*(1), 373–380.

Iftikhar, Y., Mubeen, M., Shakeel, Q., Lalarukh, I., Ali, A., Aasim, M., Zeshan, M. A., Zulfiqar, T., Alhag, S. K., & Al-Shuraym, L. A. (2024). Spatial distribution and molecular characterization of huanglongbing and its vector in various citrus cultivars. *Pakistan Journal of Agricultural Sciences, 61*(2), 685–694.

Iqbal, S., Khan, M. M., Ahmad, R., Ahmed, W., Tahir, T., Jaskani, M. J., Ahmed, S., Iqbal, Q., & Hussnain, R. (2015). Morpho-physiological and biochemical response of citrus rootstocks to salinity stress at the early growth stage. *Pakistan Journal of Agricultural Sciences, 52*, 659–665.

Karasev, A. V., Hilf, M. E., Garnsey, S. M., & Dawson, W. O. (1997). Transcriptional strategy of closteroviruses: Mapping the 5′ termini of the *Citrus tristeza virus* subgenomic RNAs. *Journal of Virology, 71*(8), 6233–6236. https://doi.org/10.1128/JVI.71.8.6233-6236.1997

Khan, A. A., Zeshan, M. A., Iftikhar, Y., Mubeen, M., Sohail, M., Bashir, S., & Ghani, M. U. (2022). Current status of *Citrus tristeza virus* in major citrus-growing areas of Sargodha, Pakistan. *Sarhad Journal of Agriculture, 38*(4), 1412–1418. https://doi.org/10.17582/journal.sja/2022/38.4.1412.1418

Lin, Y., Rundell, P. A., Xie, L., & Powell, C. A. (2006). Pre-reaction of *Citrus tristeza virus* (CTV)-specific antibodies and labelled secondary antibodies increases the speed of direct tissue blot immunoassay for CTV. *Plant Disease, 90*, 675. https://doi.org/10.1094/PD-90-0675

Liu, Y., Heying, E., & Tanumihardjo, S. A. (2012). History, global distribution, and nutritional importance of citrus fruits. *Comprehensive Reviews in Food Science and Food Safety, 11*(6), 530–545. https://doi.org/10.1111/j.1541-4337.2012.00201.x

Mahato, N., Sharma, K., Sinha, M., Dhyani, A., Pathak, B., Jang, H., Park, S., Pashikanti, S., & Cho, S. (2021). Biotransformation of citrus waste—I: Production of biofuel and valuable compounds by fermentation. *Processes, 9*(2), Article 220. https://doi.org/10.3390/pr9020220

Moreno, P., Ambrós, S., Albiach-Martí, M. R., Guerri, J., & Peña, L. (2008). *Citrus tristeza virus*: A pathogen that changed the course of the citrus industry. *Molecular Plant Pathology, 9*(2), 251–268. https://doi.org/10.1111/j.1364-3703.2007.00455.x

Mubeen, M., Arshad, H. M., Iftikhar, Y., Ullah, M. U., & Bilqees, I. (2015). Biochemical characterization of *Xanthomonas axonopodis* pv. *citri*: A Gram-negative bacterium causing citrus canker. *International Journal of Science and Nature, 6*(2), 151–154.

Mubeen, M., Bakhtawar, F., Iftikhar, Y., Shakeel, Q., Sajid, A., Iqbal, R., Aljowaie, R. M., & Chaudhary, T. (2024). Biological and molecular characterization of citrus bent leaf viroid. *Heliyon, 10*(7), Article e28209. https://doi.org/10.1016/j.heliyon.2024.e28209

Muniz, F. R., de Souza, A. J., Stipp, L. C. L., Schinor, E., Freitas, W., Harakava, R., & Mendes, B. M. J. (2012). Genetic transformation of *Citrus sinensis* with *Citrus tristeza virus* (CTV)-derived sequences and reaction of transgenic lines to CTV infection. *Biologia Plantarum, 56*(1), 162–166. https://doi.org/10.1007/s10535-012-0035-0

Naqvi, S. A., Khan, M. M., Jaskani, M. J., Mahmood, K., Basra, S. M. A., Husnain, K., & Khan, I. A. (2015). Possible role of mucilage in desiccation and germination of citrus rootstock seeds. *Pakistan Journal of Agricultural Sciences, 52*, 93–96.

Naseem, S., Mahmood, S., & Ali, Z. (2016). Occurrence of *Citrus tristeza virus* in Pakistan: A GIS-based approach combining host distribution and disease reports. *Pakistan Journal of Agricultural Sciences, 53*(3), 513–521. https://doi.org/10.21162/PAKJAS/16.3703

Roistacher, C. N., & Moreno, P. (1991). The worldwide threat from destructive isolates of *Citrus tristeza virus*: A review. In *Proceedings of the 11th Conference of the International Organization of Citrus Virologists*. https://doi.org/10.5070/C568S8K9TX

Satyanarayana, T., Gowda, S., Ayllón, M. A., & Dawson, W. O. (2004). Closterovirus bipolar virion: Evidence for initiation of assembly by minor coat protein and its restriction to the genomic RNA 5′ region. *Proceedings of the National Academy of Sciences, 101*(3), 799–804. https://doi.org/10.1073/pnas.0307747100

Shafique, T., Mubeen, M., Iftikhar, Y., Shakeel, Q., Zeshan, M. A., Lalika, H. A., & Seemab, F. (2024). ELISA-based monitoring of *Citrus tristeza virus* in declining orchards of Sargodha, Pakistan. *Sarhad Journal of Agriculture, 40*(4), 1354–1363. https://doi.org/10.17582/journal.sja/2024/40.4.1354.1363

Sharma, S. (2023). A review on *Citrus tristeza virus* (CTV) and its management approaches. *Turkish Journal of Agriculture–Food Science and Technology, 11*(4), 803–810. https://doi.org/10.24925/turjaf.v11i4.803-810.5273

Vives, M. C., Rubio, L., López, C., Navas-Castillo, J., Albiach-Martí, M. R., Dawson, W. O., Guerri, J., Flores, R., & Moreno, P. (1999). The complete genome sequence of the major component of a mild *Citrus tristeza virus* isolate. *Journal of General Virology, 80*(3), 811–816. https://doi.org/10.1099/0022-1317-80-3-811

Yaqub, M. S., Khan, I. A., Usman, M., & Rana, I. A. (2017). Molecular detection of *Candidatus Liberibacter asiaticus*, the causal organism of huanglongbing, in Faisalabad, Pakistan, for huanglongbing management. *Pakistan Journal of Agricultural Sciences, 54*, 21–26. https://doi.org/10.21162/PAKJAS/17.4455