



Viral Diseases in Mustard (*Brassica* spp.): A Comprehensive Review of Pathogens, Symptoms, and Management Strategies

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ABSTRACT: Mustard (*Brassica* spp.) is a nutritionally and economically important crucial oilseed and vegetable crop that is grown all over the world. However, the production of mustard is greatly impacted by viral infections, which result in lower quality and also yield losses. The main viral infections that harm mustard are thoroughly examined in this paper, along with their epidemiology, management approaches, and modes of transmission. Viruses most commonly spread by aphids, beetles, and mechanical means. Plant growth and seed development are hampered by symptoms such as mosaic patterns, chlorosis, vein clearing, leaf deformation, and stunting. Agronomic techniques, vector dynamics, and environmental factors all severely affect and spread of these viral infections. Cultural control methods, vector control, resistant cultivars, and molecular breeding techniques like CRISPR-Cas gene editing and RNA interference (RNAi) are examples of management strategies. Recent developments in molecular diagnostics, such as PCR and serological methods, have enhanced disease surveillance and early detection. The significance of integrated disease management (IDM) strategies which incorporate many approaches for the long term control of viral infection. Developing long lasting remedies to mitigate the effects of viral infections on mustard crops requires a deeper understanding of host-virus interactions and resistance mechanisms.

Keywords: Mustard, viral disease, Turnip Mosaic Virus, Cauliflower Mosaic Virus, Disease Management, Molecular Diagnostics.

INTRODUCTION

Mustard, which is grown for its seeds, oil, and leafy greens, is one of the economically significant crops in the genus *Brassica*. In places like North America, Europe, and South Asia, mustard is a staple oilseed crop. However, a number of pests and diseases, especially viruses that take advantage of the crop's vulnerability and cause significant financial losses, limit its production (Agrios, 2005). Mustard crop occupies highest cropping area among oilseed crop in India cultivated on 6.8 million hectare and production of 9.1 mt with average yield of 1331 kg per hectare. (Shukla *et al.*, 2024). Symptoms of viral infection in mustard and other Brassica crops are generally stunted growth, chlorosis, leaf curling, mosaic patterns, and reduce seed yield. Quick dissemination via seed materials, contaminated instruments, and insect vectors contribute to their rapid growth. Several viruses belonging to different genera infect and cause different level of losses in mustard production. To guarantee sustainable mustard production, it is crucial to comprehend these viral infections, how they interact

with mustard plants, and efficient control strategies (Singhal *et al.*, 2024). Turnip Mosaic Virus (TuMV), Cauliflower Mosaic Virus (CaMV), and Turnip Yellow Virus (TuYV) are the most prevalent and economically damaging viruses that infect mustard. These viruses are primarily disseminated by insect vectors like aphids and whiteflies, but they can also spread quickly through mechanical and, occasionally, seed-borne transmission. Effective management is a major challenge for mustard cultivators due to the high rate of viral mutation and the creation of new strains, which complicate disease. (Roberts & Driscoll 2020). Vector control, cultural practices, and integrated disease management (IDM) are the mainstays of current disease management systems. These methods, however, only offer a limited amount of control and are frequently unsustainable over time. Reverse transcription polymerase chain reaction (RT-PCR), next-generation sequencing (NGS), and enzyme-linked immunosorbent assay (ELISA) are examples of molecular diagnostic advancements that have enhanced the early detection of viral infections and contributed to improved disease surveillance. In order to create virus-resistant mustard cultivars,

advanced biotechnological techniques such as genetic engineering, RNA interference (RNAi), and CRISPR-Cas9 genome editing are also being investigated (Shahid *et al.*, 2021).

Significant knowledge gaps still exist regarding resistance mechanisms, virus-vector interactions, and the impact of environmental factors on disease outbreaks. A multidisciplinary strategy combining agriculture, molecular biology, and traditional breeding methods is needed to address these problems. A thorough examination of the main viral infections that impact mustard, their dynamics of transmission, detection techniques, and possible management approaches are what we need to understand, with current scientific developments.

Major viral disease affecting Mustard (*Brassica* spp.)

Numerous viral infections that have a substantial impact on plant vigor, yield, and overall crop output are extremely susceptible to mustard crops. Turnip Mosaic Virus (TuMV), Cauliflower Mosaic Virus (CaMV), and Turnip Yellow Virus (TuYV) are the most common and economically harmful of the several viruses that infect *Brassica* spp. (Hertel *et al.*, 2004). These viruses are extremely difficult to handle because of their complex epidemiology, high genetic variability, and wide host range. They are mostly spread by insect vectors like aphids and whiteflies.

Viral diseases in Mustard

Turnip Mosaic Virus

Genus: Potyvirus Family: Potyviridae

Host Range: Impacts a number of Brassica plants, such as radish, mustard, and cabbage.

Transmission: Aphids are the means of transmission (non-persistent method) and in mechanical means via contaminated sap.

Symptoms: Depending on the virus strain, host plant, and environmental factors, symptoms may include mosaic with leaf deformation and yellowing, especially on the outer leaves, and necrotic spots. The virus causes early senescence, collapse, and dwarfing. The quality and productivity of crops are significantly impacted by this virus. Symptoms also include mosaic patterns on leaves with regions of pale and dark green and also curling, scorching, and deformation of the leaves, Poor seed development and stunted growth.

Management: Utilizing resistant mustard cultivars is one method of management and using biological agents and pesticides to control aphids.



Fig. 1. Turnip Mosaic Virus in mustard.

Cauliflower Mosaic Virus (CaMV)

Genus: Caulimovirus Family: Caulimoviridae

Host range: Brassica crops like mustard, cabbage, cauliflower, and other crucifers.

Transmission: It disperse through Aphids in a semi-persistent way but no mechanical or seed transmission.

Symptoms: Chlorotic dots that form a distinctive "ring spot" pattern on leaves are one of the symptoms. Other symptoms include leaf deformation and vein clearing, delays in flowering and decreased plant vitality.

Management: Aphid populations are managed by using pesticides and reflecting mulches. To reduce the sources of inoculum, infected plant debris should be removed. Breeding is used to create resistant mustard cultivars.



Fig. 2. Cauliflower Mosaic Virus (CaMV) in mustard.

TYMV, or Turnip Yellow Mosaic Virus

Genus: Tymovirus Family: Tymoviridae

Host range: infects cruciferous vegetables such as mustard, turnip, and radish.

Transmission: The primary method of transmission is via beetles, specifically flea beetles (*Phyllotreta* spp.).

Transmission by mechanical means via contaminated sap. **Symptoms:** Symptoms include thickening of the leaves and yellow mosaic patterns. Vein clearance and severe chlorosis. Decreased seed production and growth retardation.

Management: Using chemical and biological techniques to control flea beetles. The use of resistant cultivars and seeds free of viruses. Controlling weeds properly to get rid of virus reservoirs. (Chaoudhary & Yadav 2022)



Fig. 3. Turnip Yellow Mosaic Virus in brassica in brassica.

Beet Western Yellows (BWYV)

Genus: Polerovirus **Family:** Luteoviridae

Host range: dicot plants such as lettuce, mustard, and sugar beet.

Transmission: Persistent circulative transmission by aphids (*Myzus persicae*). No seed or mechanical transmission.

Symptoms: Interveinal chlorosis and vein clearance. Reduced seed and delayed flowering. **Management:** Systemic pesticides are used to control vectors. The introduction of mustard cultivars resistant to BWYV. The early identification and removal of contaminated plants (Latham & Jones 2003).



Fig. 4. Beet Western Yellows (BWYV).

CMV, or Cucumber Mosaic Virus – Genus: *Cucumovirus*

Family: Bromoviridae

Host range: Impacts more than 1,000 plant species, such as pepper, tomato, cucumber, and mustard.

Transmission: Transmission by Aphids disperse it in a non-persistent way. Transmission by mechanical means via contaminated sap.

Symptoms: Symptoms include mottling and mosaic on mustard leaves. Stunted growth, deformation, and curling of the leaves. Low oil content and poor seed set.

Management: Using mustard cultivars that are tolerant or resistant. Using insecticides and bio-pesticides to control aphids. Eliminating weeds and infected plants to stop the virus from spreading (Chen, 2010).



Fig. 5. Cucumber Mosaic Virus.

TVCV, or Turnip Vein Clearing Virus

Genus: Tobamovirus **Family:** Tobamoviridae

Host range: Mustard, turnip, radish, and other crucifers.

Transmission: Mechanical transfer by contaminated tools and sap. There is no insect vector present.

Symptoms: Young leaves with chlorosis and vein clearing. Leaf deformation and necrotic patches. Plant stunting and yield loss are caused by severe infections.

Management: Using hygienic procedures to stop mechanical spread. Utilizing varieties of resistant mustard. Steer clear of handling contaminated plants while conducting fieldwork (Lockhart *et al.*, 2007).

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Fig. 6. Turnip Vein Clearing Virus.

Oilseed Rape Mosaic Virus (ORMV)

Genus: Tobamovirus **Family:** Virgaviridae

Host range: Mustard, oilseed rape, radish, and other Brassica crops.

Transmission: Mechanical transmission through contaminated hands, tools, and plant waste is one method of transmission. No seed transmission or insect vector.

Symptoms: include mosaic mottling on leaves, which resembles TMV infections. Reduced oil and seed yield due to stunted plant growth.

Management: Keeping farming implements and equipment clean. Using seeds that have been confirmed virus-free. The creation of varieties of resistant mustard (Mansilla *et al.*, 2009).



Fig. 7. Oilseed Rape Mosaic Virus (ORMV).

Additional New Viral Diseases in Mustard-

In addition to the viruses mentioned above, a number of newly discovered viral diseases are being reported more frequently in areas that cultivate mustard. These include Beet Western Yellows Virus (BWYV), Turnip Crinkle Virus (TCV), and Cabbage Leaf Curl Virus (CaLCV). Climate change, vector population dynamics, and intensive agricultural practices are the main causes of these viruses' emergence, making ongoing research and surveillance essential to the creation of efficient control plans.

Mustard Virus Epidemiology and Transmission

Aphids like *Myzus persicae* and *Brevicoryne brassicae* are known to carry TuMV, CaMV, CMV and BWYV. Aphids spread these viruses by consuming mustard plants.

Beetle -Mediated Transmission include Flea beetles (*Phyllotreta* spp.) which feed on mustard leaves and create wound that allow the virus to enter, that is how TYMV is transmitted. Mechanical transmission seen through direct plant contact and contaminated tools are the means by which TVCV and ORMV are transmitted. Transmission rates may increase by human handling in field activities (Smith *et al.*, 2021).

Strategies for Integrated Management of Mustard Viral Diseases

Avoid planting mustard in fields that have been affected by viruses through crop rotation. It is important to remove and dispose of infected plants and plant debris for proper field sanitation. Reflective mulches can repel insect vectors, such as aphids and beetles. To manage aphids and beetles, insecticides like pyrethroids and neonicotinoids can be applied, or biological control can be used by introducing parasitic and predatory insects, such as ladybugs. Virus-resistant mustard varieties can be developed using both biotechnology and traditional breeding methods. Additionally, introducing resistance-gene Brassica germplasm can improve resistance to viruses. CRISPR-Cas genome editing can be used to alter susceptibility genes to provide viral resistance, while RNA interference (RNAi) can silence specific genes to prevent the spread of viruses. To detect viral infections early, PCR and RTPCR can be used to find viral RNA in mustard plants, and ELISA allows for the rapid identification of virus-specific proteins (Thompson *et al.*, 2022).

DISCUSSION AND CONCLUSION

The sustainable production of mustard, a vital oilseed crop within the Brassica genus, is increasingly threatened by a range of viral pathogens that compromise both yield and quality (Sharma *et al.*, 2021). Despite advancements in molecular diagnostics and biotechnological interventions, viral infections—particularly those caused by TuMV, CaMV, and TuYV continue to pose a formidable challenge due to their rapid mutation rates and diverse transmission mechanisms. The vector-mediated transmission and the quick evolution of virus strains provide significant obstacles to disease control (Kaur & Sandhu 2019). The reliance on chemical control and vector management, though partly effective, calls for more sustainable and integrated approaches.

Further research into virus-host interactions, vector ecology, and the influence of environmental variables is essential to develop resilient mustard cultivars and sustainable disease management systems. Ultimately, enhancing our understanding of viral pathogenesis and deploying innovative technologies will be key to securing the future of mustard cultivation globally. This review comprehensively highlights the various viral pathogens affecting mustard (*Brassica* spp.), elucidating their symptomatology, modes of transmission, and current management strategies. Our analysis emphasizes the urgent need for early detection tools, host resistance breeding. The role of environmental factors, particularly climate change, in influencing disease dynamics also emerged as a crucial consideration for future disease forecasting and management strategies.

FUTURE SCOPE

Looking ahead, the integration of advanced omics technologies—such as genomics, transcriptomics, and proteomics—offers immense potential to unravel the complex interactions between mustard plants and viral

pathogens. These approaches can facilitate the identification of resistance genes and biomarkers associated with virus tolerance, accelerating the development of resistant cultivars through marker-assisted selection and genome editing tools like CRISPR-Cas9. Additionally, the application of artificial intelligence (AI) and big data analytics in plant disease forecasting can revolutionize early warning systems, enabling timely interventions and minimizing crop losses. Expanding research into virus-vector ecology, especially under changing climatic conditions, is also critical to predicting and mitigating future outbreaks. Moreover, integrating traditional knowledge systems with modern agricultural practices may provide novel insights into sustainable disease management. Collaborative efforts across disciplines—spanning plant virology, entomology, breeding, and data science—will be essential to build resilient mustard production systems and ensure food and economic security in virus-prone regions.

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Conflict of Interest. None.

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