Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 04, Issue: 06 (NOV-DEC, 2024)
Available online at http://www.agriarticles.com

Mycoviruses: Natural Allies in the Fight against Plant Pathogenic Fungi

(*D.M. Parmar[1] and P.M. Patel[2])
[1]Department of Plant Pathology, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India
[2]College of Horticulture, Sardar Krushinagar Dantiwada Agricultural University, Jagudan, Gujarat, India
*Corresponding Author's email: darshanparmar3133@gmail.com

In the ever-evolving battle between plants and pathogens, researchers are continuously seeking innovative solutions to protect crops and ensure global food security. One of the most promising, yet underexplored, allies in this fight comes from mycoviruses—viruses that specifically infect fungi. Mycoviruses, also known as fungal viruses, are viruses that replicate within fungal cells. They were first identified in diseased mushrooms (*Agaricus bisporus*) and in species of Penicillium, which are known to enhance interferon production in mammals (Xie and Jiang, 2014). Unlike their plant or animal counterparts, mycoviruses are unique in that they do not typically cause harm to their fungal hosts (Khan *et al*., 2023). Instead, they have the potential to modulate fungal behaviour, reduce virulence, and suppress the ability of pathogenic fungi to cause diseases in plants (Xie and Jiang, 2014). This emerging field of study holds great promise for revolutionizing plant disease management.

Recent research has uncovered the potential of mycoviruses to act as biological control agents, capable of naturally inhibiting the growth and spread of harmful plant pathogens. As chemical-based plant protection strategies face increased scrutiny due to environmental concerns, mycoviruses offer a sustainable alternative that could reshape modern agriculture. By leveraging the natural interactions between mycoviruses and their fungal hosts, scientists are exploring new pathways to mitigate fungal diseases that threaten crops worldwide.

This article delves into the fascinating world of mycoviruses, exploring their biology, mechanisms of action, and their role as natural allies in combating plant pathogens. It also highlights the potential applications of mycoviruses in sustainable agriculture, offering a glimpse into their future role in integrated pest management strategies.

Mechanism of Mycoviruses Infecting Plant Pathogens

Mycoviruses infect fungal pathogens through intracellular replication, altering the behaviour and physiology of their fungal hosts. Unlike many other viruses that have an extracellular phase, mycoviruses are typically transmitted vertically from one fungal generation to the next or horizontally through the hyphal anastomosis, where two fungal cells fuse and share cytoplasmic contents. Here's an overview of the key mechanisms by which mycoviruses infect and affect plant pathogens:

- **Transmission and entry:** Mycoviruses primarily spread within fungal populations through two mechanisms. Vertical transmission occurs during fungal reproduction, passing mycoviruses from parent to offspring *via* spores. Horizontal transmission occurs through hyphal fusion, where fungal hyphae from different individuals merge, allowing the exchange of cytoplasmic contents, including viral particles (Hillman and Milgroom, 2021). Mycoviruses lack an extracellular phase, which limits their transmission to these direct forms of interaction between fungi.

- **Replication inside the host:** Once inside the fungal cells, mycoviruses replicate within the cytoplasm, often without causing apparent symptoms in their hosts (Ghabrial and Suzuki, 2009). The viral genome, which is usually composed of double-stranded RNA (dsRNA) or, in some cases, single-stranded RNA (ssRNA), utilizes the fungal cell's replication machinery to reproduce. Infected fungi carry these viral particles in all their cells.
- **Hypovirulence induction:** One of the most significant effects of mycovirus infection is the induction of hypovirulence in the fungal host. Hypovirulent strains exhibit reduced pathogenicity, meaning they cause less severe diseases in plants. For example, the well-known *Cryphonectria hypovirus* 1 (CHV1) in *Cryphonectria parasitica*, the fungus responsible for chestnut blight, is a classic example where mycovirus infection greatly reduces the fungus's ability to cause damage (Alfen *et al*., 1975, Anagnostakis, 1982 and Nuss, 1992).
- **Alteration of fungal growth and development:** Mycoviruses can alter the growth, reproduction and morphology of fungal pathogens. Some infected fungi experience slower growth rates, reduced spore production, and weakened ability to colonize plant tissues (Pearson *et al*., 2009). This growth inhibition is particularly beneficial in biocontrol efforts, as it reduces the fungus's capability to spread and cause disease.
- **Suppression of virulence factors:** Mycoviruses often suppress the expression of virulence factors in fungal pathogens (Nuss, 2005). These factors are typically enzymes or toxins that fungi produce to attack plant tissues. By disrupting the production of these harmful compounds, mycoviruses can reduce the severity of fungal infections in plants, helping protect crops from significant damage.
- **Involvement in host defense suppression:** Some mycoviruses can interfere with the fungal host's ability to counteract plant defense mechanisms (Nuss, 2005). This weakens the fungus's ability to overcome the plant’s immune responses, further limiting the severity of the infection. As a result, plants are better able to resist diseases caused by mycovirus-infected fungi.
- **vii) Impact on ecological fitness:** Infected fungi may also experience reduced ecological fitness, leading to diminished competition against non-infected fungal strains or other microorganisms. This can result in lower fungal populations and a reduced spread of plant diseases in agricultural environments.

Mycoviruses in Plant Disease Management

Mycoviruses are widespread in fungal populations and exhibit diverse effects on their hosts, ranging from neutral coexistence to pathogenicity enhancement or suppression. Of particular interest are hypovirulent mycoviruses, which can attenuate the virulence of their fungal hosts, rendering them less damaging to plants. This unique property has led to the investigation of mycoviruses as biological control agents against a variety of fungal diseases. Here is the table summarizing role of some mycoviruses in management of plant disease management.

Table 1: Successful examples of mycoviruses mediated plant disease management

Crop	Mycovirus	Pathogen Controlled	References
Grapevine	*Botrytis cinerea mitovirus 2* (BcMV2)	*Botrytis cinerea* (Gray mold)	Wu *et al.* (2010)
Tomato	*Rosellinia necatrix megabirnavirus 1* (RnMBV1)	*Rosellinia necatrix* (White root rot)	Kanematsu *et al.* (2010)

Rice	*Sclerotinia sclerotiorum mycoreovirus 4* (SsMV4)	*Sclerotinia sclerotiorum* (Rice sheath blight)	Yu *et al*. (2013)
Peanut	*Aspergillus flavus cryptic virus* (AfCV)	*Aspergillus flavus* (Aflatoxin production)	Eaton *et al*. (2015)
Apple	*Penicillium expansum partitivirus 1* (PePV1)	*Penicillium expansum* (Blue mold)	Nerva *et al*. (2016)
Banana	*Fusarium oxysporum* f. sp. *cubense virus 1* (FoCV1)	*Fusarium oxysporum* (Panama disease)	Liang *et al*. (2018)
Chestnut	*Cryphonectria hypovirus 1* (CHV1)	*Cryphonectria parasitica* (Chestnut blight)	Hillman *et al*. (2018)
Wheat	*Rosellinia necatrix partitivirus 1* (RnPV1)	*Fusarium graminearum* (Wheat scab)	Ahn *et al*. (2019)
Common Bean	*Beauveria bassiana hypovirus 1* (BbHV1)	*Beauveria bassiana*	Xie *et al*. (2020)
Cucumber	*Fusarium oxysporum* f. sp. *cucumerinum mycovirus 1* (FoCV1)	*Fusarium oxysporum* (Wilt)	Kotta-Loizou (2020)
Peppers	*Botrytis cinerea mitovirus 1* (BcMV1)	*Botrytis cinerea* (Gray mold)	Jurado *et al*. (2020)
Soybean	*Sclerotinia sclerotiorum hypovirus 2* (SsHV2)	*Sclerotinia sclerotiorum* (White mold)	Jiang *et al*. (2021)
Potato	*Phytophthora infestans RNA virus 1* (PiRV1)	*Phytophthora infestans* (Late blight)	Cai *et al*. (2022)

Conclusion

Mycoviruses are potential biological control agents in managing plant diseases caused by fungal pathogens. These viruses can reduce the virulence of fungi, suppress mycotoxin production, and impair the fitness of harmful fungal species, offering an eco-friendly alternative to chemical fungicides. Successful applications in controlling diseases like chestnut blight and white mold demonstrate their value in crop protection. However, challenges remain, including host specificity, transmission limitations and ensuring viral stability in field conditions. Regulatory and biosafety concerns also require careful evaluation before releasing mycoviruses into the environment. Advances in genomics and biotechnology are helping overcome these hurdles, enhancing the efficacy and field application of mycoviruses. As research progresses, mycoviruses could play a vital role in integrated pest management, providing a sustainable solution for fungal disease control. Overall, continued research and innovation are essential to harness the potential of mycoviruses in plant disease management.

References

1. Ahn, I., Lee, Y. and Hong, K. (2019). Mycoviruses as a potential biological control agent of *Fusarium graminearum*. *Frontiers in Microbiology*, 10, 2706.
2. Alfen, N.K., Jaynes, R.A., Anagnostakis, S.L. and Day, P.R. (1975). Chestnut blight: biological control by transmissible hypovirulence in *Endothia parasitica*. Science, 189(4206), 890-891.
3. Anagnostakis, S.L. (1982). Genetic analyses of *Endothia parasitica*: linkage data for four single genes and three vegetative compatibility types. *Genetics*, 102(1), 25-28.
4. Cai, G., Myers, K. and Hansen, E. (2022). A new RNA virus in *Phytophthora infestans* and its potential role in reducing late blight disease. *Virology Journal*, 19, 55.

5. Eaton, C.J., Cox, M.P. and Scott, B. (2015). Cryptic *Aspergillus flavus* viruses reduce aflatoxin production. *Applied and Environmental Microbiology*, 81(17), 5887–5895.
6. Ghabrial, S.A. and Suzuki, N. (2009). Viruses of plant pathogenic fungi. *Annual review of phytopathology*, 47(1), 353-384.
7. Hillman, B.I. and Milgroom, M.G. (2021). The ecology and evolution of fungal viruses. *Studies in Viral Ecology*, 139-182.
8. Hillman, B.I., Annisa, A. and Suzuki, N. (2018). Viruses of plant-interacting fungi. *Advances in Virus Research*, 100, 99–116.
9. Jiang, D., Fu, Y. and Xie, J. (2021). *Sclerotinia sclerotiorum* hypoviruses and their role in biological control. *Annual Review of Plant Pathology*, 59, 77–98.
10. Jurado, I., Duenas, M., Melero, I. and Velazquez, E. (2020). Biocontrol potential of *Botrytis cinerea mitovirus 1* against gray mold disease. *Journal of Plant Pathology*, 102(3), 657–667.
11. Kanematsu, S., Sasaki, A. and Myers, C. (2010). Genome organization of *Rosellinia necatrix megabirnavirus 1*: A novel, bicistronic, double-stranded RNA virus that infects a phytopathogenic fungus. *Journal of General Virology*, 91, 232–240.
12. Khan, H.A., Mukhtar, M. and Bhatti, M.F. (2023). Mycovirus-induced hypovirulence in notorious fungi Sclerotinia: a comprehensive review. *Brazilian Journal of Microbiology*, 54(3), 1459-1478.
13. Kotta-Loizou, I. (2020). Mycoviruses in *Fusarium* species: An overview. *Pathogens*, 9(7), 493.
14. Liang, X., Luo, Y., Li, M. and Gao, J. (2018). *Fusarium oxysporum* f. sp. *cubense* virus 1 as a novel biocontrol agent for Panama disease in bananas. *Molecular Plant Pathology*, 19(9), 1995–2004.
15. Nerva, L., Varese, G.C. and Turina, M. (2016). Biological control potential of *Penicillium expansum partitivirus 1* against blue mold disease in apples. *Plant Pathology*, 65(6), 1244–1253.
16. Nuss, D.L. (1992). Biological control of chestnut blight: an example of virus-mediated attenuation of fungal pathogenesis. *Microbiological reviews*, 56(4), 561-576.
17. Nuss, D.L. (2005). Hypovirulence: mycoviruses at the fungal–plant interface. *Nature Reviews Microbiology*, 3(8), 632-642.
18. Pearson, M.N., Beever, R.E., Boine, B. and Arthur, K. (2009). Mycoviruses of filamentous fungi and their relevance to plant pathology. *Molecular Plant Pathology*, 10(1), 115-128.
19. Wu, M., Jin, F., Zhang, J., Yang, L., Jiang, D., Li, G. and Xie, J. (2010). Characterization of *Botrytis cinerea mitovirus 2*, a novel mycovirus with a unique genome organization. *Virology*, 403(2), 240–248.
20. Xie, J. and Jiang, D. (2014). New insights into mycoviruses and exploration for the biological control of crop fungal diseases. *Annual Review of Phytopathology*, 52(1), 45-68.
21. Xie, J., Wei, D., Jiang, D., Fu, Y., Li, G. and Ghabrial, S.A. (2020). Mycoviruses in fungal biological control agents. *Annual Review of Phytopathology*, 58, 9.1–9.22.
22. Yu, X., Li, B., Fu, Y., Jiang, D., Ghabrial, S.A., Li, G., Peng, Y., Xie, J., Cheng, J., Huang, J. and Yi, X. (2013). A geminivirus-related DNA mycovirus that confers hypovirulence to a plant pathogenic fungus. *Proceedings of the National Academy of Sciences*, 110(18), 7768–7773.