



BIOLOGICAL CONTROL OF FUSARIUM WILT IN TOMATO USING TRICHODERMA spp.: MECHANISMS AND APPLICATION PROSPECTS

Lola Abduholiqovna Suyunova

Karshi state technical university,

e-mail: lolasuyunova870@gmail.com

Abstract

The present review examines the potential application of *Trichoderma* spp. as biological control agents against Fusarium wilt of tomato (*Solanum lycopersicum* L.), caused by *Fusarium oxysporum* f. sp. *lycopersici*. Fusarium wilt is an economically important soil-borne disease that affects tomato growth, vascular function, and productivity. Biological control using beneficial microorganisms represents a promising approach for reducing dependence on synthetic fungicides. This review analyzes the principal antagonistic mechanisms of *Trichoderma* spp., including mycoparasitism, competition for nutrients and colonization sites, production of antifungal metabolites, secretion of cell-wall-degrading enzymes, and induction of plant defense responses. Published studies indicate that the effectiveness of *Trichoderma*-based treatments depends on fungal strain characteristics, environmental conditions, application methods, and interactions with the plant rhizosphere. The findings highlight the potential of locally adapted *Trichoderma* isolates for developing sustainable biological plant protection technologies. Further laboratory, greenhouse, and field investigations are required to evaluate their efficacy under the agroecological conditions of Uzbekistan.

Keywords

Trichoderma harzianum, *Trichoderma asperellum*, *Fusarium oxysporum*, tomato, biological control, plant protection, antagonistic activity, biopesticides.

Introduction



Tomato (*Solanum lycopersicum* L.) is an important vegetable crop cultivated worldwide for its nutritional and economic value. However, its production is frequently affected by fungal diseases, among which Fusarium wilt is particularly destructive. The causal pathogen, *Fusarium oxysporum* f. sp. *lycopersici*, colonizes the vascular tissues of tomato plants, disrupting water transport and causing yellowing, wilting, and, in severe cases, plant death [1].

Conventional management of soil-borne fungal diseases includes resistant cultivars, crop rotation, soil treatment, and chemical fungicides. Nevertheless, the persistence of fungal pathogens in soil and environmental concerns associated with chemical treatments encourage the development of alternative biological protection strategies.

Species belonging to the genus *Trichoderma* are widely recognized as beneficial soil fungi capable of suppressing several phytopathogens. Their antagonistic properties are associated with mycoparasitism, antifungal metabolite production, nutrient competition, and stimulation of plant defense mechanisms [2].

The importance of microbial biological control has also been emphasized in recent research addressing the management of *F. oxysporum* f. sp. *lycopersici* [3].

Therefore, the objective of this review is to evaluate the major mechanisms involved in the biological suppression of tomato Fusarium wilt by *Trichoderma* spp. and identify potential directions for developing effective microbial biopesticides.

Materials and Methods. The present work was conducted as a literature-based scientific review. Published research articles addressing the biological control of tomato Fusarium wilt, the antagonistic activity of *Trichoderma* species, and plant–microorganism interactions were examined.

The review focused on three principal aspects: the biological characteristics of the pathogen, the antagonistic mechanisms of *Trichoderma* spp., and the prospects for



practical application of fungal biological control agents. Information was synthesized from peer-reviewed publications covering phytopathology, agricultural microbiology, and plant biotechnology. Particular attention was given to mechanisms supported by experimental investigations, including pathogen inhibition, fungal interactions, and induced plant resistance.

No new laboratory experiments were performed as part of this review.

Results and Discussion

The literature analysis indicates that *Trichoderma* spp. possess several biological characteristics that make them promising candidates for controlling soil-borne phytopathogenic fungi.

One of the major mechanisms is mycoparasitism, during which antagonistic fungi interact directly with pathogenic fungal hyphae. Certain *Trichoderma* strains produce extracellular hydrolytic enzymes, including chitinases and glucanases, which contribute to the degradation of fungal cell-wall components [2].

Another important mechanism is antibiosis. *Trichoderma* species can produce secondary metabolites with antifungal activity. These substances may inhibit pathogen growth and contribute to disease suppression.

Furthermore, successful colonization of the rhizosphere allows certain strains to compete with pathogenic microorganisms for available nutrients and ecological niches.

Research also demonstrates that *Trichoderma*–plant interactions can activate defense-related responses and promote root development, potentially improving plant tolerance to pathogen infection [2].

Table 1. Principal mechanisms of biological control by *Trichoderma* spp. against fungal plant pathogens



Biological mechanism	Mode of action	Potential significance
Mycoparasitism	Direct interaction with pathogen hyphae	Suppression of fungal development
Antibiosis	Production of antifungal metabolites	Inhibition of pathogen growth
Enzymatic activity	Secretion of chitinases and glucanases	Degradation of fungal cell walls
Nutrient competition	Competition for nutrients and colonization sites	Restriction of pathogen establishment
Induced resistance	Activation of plant defense responses	Improved resistance to infection
Root colonization	Establishment of beneficial root associations	Promotion of plant growth and nutrient uptake

The mechanisms summarized in Table 1 are derived from published investigations of *Trichoderma*–pathogen and *Trichoderma*–plant interactions [2, 3]. Their relative importance may differ between fungal strains and environmental conditions.

For agricultural application, strain selection is particularly important. A microorganism demonstrating strong antagonistic activity under laboratory conditions may not necessarily provide equivalent protection under greenhouse or field conditions.

Consequently, the development of *Trichoderma*-based biological products requires additional evaluation of formulation stability, microbial viability, rhizosphere adaptation, application methods, and compatibility with existing crop management practices. Under the conditions of Uzbekistan, the isolation and screening of indigenous *Trichoderma* strains from agricultural soils may represent a useful research direction. Such investigations could support the development of locally adapted biological preparations for tomato protection.



Conclusion

The reviewed scientific literature demonstrates that *Trichoderma* spp. represent promising biological agents for the management of fungal plant diseases, including Fusarium wilt of tomato.

Their protective potential is associated with several complementary mechanisms, including mycoparasitism, antibiosis, nutrient competition, enzymatic degradation of pathogen structures, and stimulation of plant defense responses.

The development of effective microbial preparations requires the selection of highly active antagonistic strains and their evaluation under different cultivation conditions.

Future investigations should focus on isolating locally adapted *Trichoderma* strains, determining their antagonistic activity against *Fusarium oxysporum* f. sp. *lycopersici*, and evaluating their biological effectiveness in greenhouse and field experiments. These approaches may contribute to environmentally sustainable plant protection and reduce reliance on conventional chemical fungicides.

References

Srinivas, C., Nirmala Devi, D., Narasimha Murthy, K., et al. (2019). *Fusarium oxysporum* f. sp. *lycopersici* causal agent of vascular wilt disease of tomato: Biology to diversity—A review. *Saudi Journal of Biological Sciences*, 26(7), 1315–1324. <https://doi.org/10.1016/j.sjbs.2019.06.002>

Harman, G. E., Howell, C. R., Viterbo, A., Chet, I., & Lorito, M. (2004). *Trichoderma* species—opportunistic, avirulent plant symbionts. *Nature Reviews Microbiology*, 2, 43–56. <https://doi.org/10.1038/nrmicro797>

Anand, V., & Yadav, U. (2026). Biological control of the soil-borne fungal pathogen *Fusarium oxysporum* f. sp. *lycopersici*—a review. *Canadian Journal of Microbiology*, 72, 1–9. <https://doi.org/10.1139/cjm-2025-0232>