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Eco-Friendly Plant Disease Management: The Case for *Trichoderma viride*

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Trichoderma is a genus of filamentous fungi commonly found in soil and root ecosystems. *T. viride* is one of the most studied species due to its remarkable biocontrol properties and ease of commercial production. It is naturally occurring, non-toxic, and compatible with organic farming systems.

The increasing demand for sustainable agricultural practices has brought biological control agents into the spotlight. Among these, *Trichoderma* species—particularly *Trichoderma viride*—have emerged as a powerful ally in eco-friendly plant disease management. Known for their effectiveness against a range of plant pathogens, *Trichoderma* fungi offer an environmentally safe alternative to chemical fungicides.

Trichoderma - Plants Interactions

In recent years, *Trichoderma* has acquired high importance because of its fungicidal and fertilizing potential. In exchange for sucrose from plants, fungi exert numerous advantageous influences on plants. Among them should be mentioned the induction of rapid plant development and production, an increase in nutrient absorption, rhizosphere modification and tolerance improvement to both biotic and abiotic stresses. *Trichoderma* is attracted by chemical signals released by a plant's root. The initial steps of symbiosis establishment involve attachment and penetration and colonization of *Trichoderma* within the plant roots. Plant root anchoring is facilitated by cysteine-rich proteins known as hydrophobin, e.g., TasHyd1 hydrophobins were obtained *from T. asperellum and T. harzianum*, respectively. After successful attachment, root invasion is promoted by emission of expansin-like proteins. They exhibit cellulose binding modules as well as express endopolygalacturonase activity. Furthermore, successful penetration of Trichoderma is followed by a rapid colonization of root tissues, which is achieved by lowering plant defenses, such as phytoalexin production, as previously observed in *Lotus japonicus* roots during *T. koningii* penetrations. Moreover, in pathogen contaminated soil, Trichoderma spp. cooperate with other beneficial microbial populations, improving plant growth and survival.

Effect of *Trichoderma* on Climate Change

1. Enhancing Carbon Sequestration: *Trichoderma* improves plant root growth and soil structure, encouraging the formation of soil organic matter.

Healthier roots and microbial activity help store carbon in soil, reducing the amount of CO_2 in the atmosphere.

2. Reducing Dependence on Chemical Fertilizers: *Trichoderma* promotes nutrient uptake (like phosphorus and nitrogen) and fixes nutrients in the soil.

This can reduce the need for synthetic fertilizers, whose production and application are energy-intensive and emit greenhouse gases (especially nitrous oxide).

3. Improving Plant Resilience to Climate Stress: *Trichoderma* helps plants withstand drought, heat, and salinity, which are worsened by climate change.

It induces systemic resistance, allowing crops to thrive in more extreme conditions, supporting climate-resilient agriculture.

4. Biological Control Agent: *Trichoderma* suppresses plant pathogens, reducing the need for chemical pesticides, which also contribute to GHG emissions and environmental degradation.

5. Waste Decomposition & Soil Remediation: *Trichoderma* species are involved in the biodegradation of organic waste and bioremediation of polluted soils, reducing methane emissions from waste and improving degraded lands for agriculture or carbon capture.

Methods of Application in Soil

1. Seed Treatment: Mix *Trichoderma* powder or formulation (usually 4–10 g/kg seed) with water or an adhesive like jaggery.Coat the seeds evenly before sowing.

This helps protect seedlings from soil-borne pathogens right from germination.

2. **Soil Application:** Mix 1–2 kg of *Trichoderma* formulation (containing 1×10^7 to 1×10^8 CFU/g) with 100 kg of well-decomposed compost or farmyard manure (FYM).

Broadcast it in the field before final plowing or just before planting. Ideal for controlling soil-borne diseases like damping-off, root rot, and wilt.

3. Nursery Bed Treatment: Mix 50–100 g of *Trichoderma* with 10–20 kg of compost.

Apply uniformly to the nursery bed soil.Ensures protection during early growth stages.

4. Drip Irrigation or Soil Drenching: Dissolve 10–20 g/liter (or per manufacturer's recommendation) of *Trichoderma* in water.Apply around plant root zones.

Used in established crops for disease suppression and promoting root development.

Mode of action

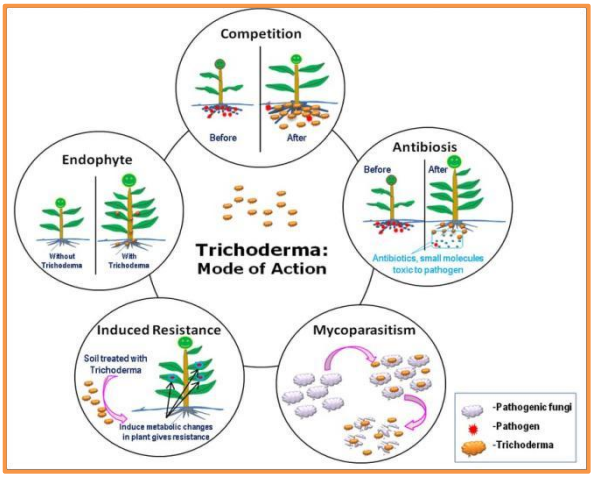
Mycoparasitism: *Trichoderma* fungi can directly attack and feed on other fungal pathogens, potentially killing or limiting their growth.

Antibiosis: *Trichoderma* produces secondary metabolites, including antibiotics and toxins, that inhibit the growth of other organisms, including plant pathogens.

Competition: *Trichoderma* can compete with pathogens for nutrients and space in the rhizosphere, reducing the availability of resources for pathogen growth.

Induced Systemic Resistance: *Trichoderma* can trigger the plant's defense responses, enhancing its resistance to future pathogen attacks.

Plant Growth Promotion: Some *Trichoderma* species can also promote plant growth by producing plant growth regulators or solubilizing nutrients



Benefits of *Trichoderma* in Soil

1. Biocontrol Agent: Suppresses soil-borne pathogens like *Fusarium, Rhizoctonia, Pythium,* and *Sclerotium*.Competes for nutrients and space, parasitizes pathogens, and secretes antifungal compounds.

2. Improves Soil Health: Enhances microbial biodiversity.Improves organic matter decomposition.

3. **Promotes Plant Growth:** Produces plant hormones like auxins and gibberellins.

4. Enhances Resistance: Induces systemic resistance in plants against future pathogen attacks.

Challenges and Considerations

1. Storage and Shelf Life: Bioformulations must be stored properly to maintain viability.
2. Compatibility: May not be compatible with certain chemical fungicides.
3. Environmental Conditions: Effectiveness can be influenced by temperature, pH, and soil moisture.

Conclusion

Trichoderma viride presents a promising, eco-friendly approach to managing plant diseases by utilizing its natural biocontrol capabilities. This fungal species effectively suppresses plant pathogens through various mechanisms, including competition, antibiosis, and induced systemic resistance, offering a sustainable alternative to chemical pesticides. By incorporating *Trichoderma viride* into plant disease management strategies, farmers can improve plant health, reduce environmental impact, and promote sustainable agricultural systems.

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