



## Trichoderma: Mode of Action and Application Methods for Crop Disease Management

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### Abstract

Indiscriminate use of fungicides in agriculture has done great harm to the environment including humans. Biological control is now being considered as the key method of disease control in view of healthy ecosystem. Biological control is the use of bioagents to suppress the capacity and population of pathogen. It is particularly desirable because the tactic is environmentally safe, energy self-sufficient, cost-effective, sustainable, and can be readily incorporated into integrated disease management programs. Most biological control methods aim at improving the resistance of the host or favoring microorganisms antagonistic to the pathogen. Bioagents destroy or suppress the pathogen through antagonism *i.e.*, antibiosis, competition, parasitism and exploitation. *Trichoderma* spp. serves as one of the best bioagents and it found to be effective against a wide range of soil, seed and air borne pathogens without damaging the environment.

**Keywords:** Antibiosis, Biological control, Competition, Trichoderma

### Introduction

Agriculture is the main source of our food supply to sustain on the earth and it also helps to grow our economy across the world. Agricultural crops are vulnerable to attack number of pests including bacteria, fungi, weed and insects, leading to reduced yield and poor quality of the produce. Most of the plant pathogens, which cause important diseases in crops, are seed and soil borne in nature. Fungicides play an important role in management of plant pathogens. However, the soil borne plant pathogens are often difficult to manage with the fungicides and other ordinary methods due to their limitations to perform better against to pathogens. In recent years, indiscriminate and expensive use of pesticides has posed a serious problem of pollution in the ecosystem and development of resistance in the pathogens. While the farmer is exemplified by pesticide residues in soil, air, water, food *etc.*, the latter includes phytotoxicity, physiological deformities, diseases, mortality, population changes, genetic disorders, gene erosion, *etc.* in plant, mammal, avian, insect and other organisms. Therefore, biological control of pathogens has gained importance as component of integrated disease management for sustainable agriculture as it is a long lasting and eco-friendly. Currently, several bio-

control agents have been recognized and are available as fungal agents *i.e.*, *Trichoderma* spp., *Gliocladium virens*, *G. roseum*, *Aspergillus niger*, *A. flavus*, *Chaetomium globosum*, *Ampelomyces* spp., *Candida* spp., and *Coniothyrium* spp. and bacterial agents like *Bacillus subtilis*, *B. cereus*, *Pseudomonas fluorescens*, *Agrobacterium radiobacter* *etc.* (Agrios, 2005). Among these biocontrol agents *Trichoderma* spp. is one of the most versatile bio-control agents which have long been used for managing the plant pathogenic fungi.

### Trichoderma and Its Habitat

Trichoderma term has been derived from two words thrix (hair means thread like) and derma (skin). Genus *Trichoderma* is a soil inhabiting green filamentous fungus, which belongs to the division Ascomycota that reproduce asexually. It has been proven in numerous studies that *Trichoderma* spp. are effective biocontrol agents for managing plant disease (Table 1), and currently commercial products of *Trichoderma* are available as biopesticides or soil amendments or as enhancers for plant growth (Papavizas, 1985; Vinale *et al.*, 2008). The efficacy of *Trichoderma* depends on many abiotic parameters such as soil pH, water retention, temperature and presence of heavy metals. The genus *Trichoderma*

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Table 1: List of crop diseases and their management through application of *Trichoderma* spp.

Crop Name	Disease Name	Causative agent	Effective <i>Trichoderma</i> spp.	Mode of application
<b>Vegetable crops</b>				
Brinjal	Wilt, damping off	<i>F. solani</i> , <i>P. aphanidermatum</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i> , <i>T. virens</i>	Seed and soil treatment
	Collar rot	<i>Sclerotinia sclerotiorum</i>	<i>Trichoderma viride</i> , <i>T. virens</i>	Soil treatment
Chilli	Root rot	<i>Sclerotium rolfsii</i>	<i>Trichoderma harzianum</i> , <i>T. viride</i>	Soil treatment
Tomato	Damping off	<i>Pythium indicum</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Seed and soil treatment
	Seedling wilt	<i>Fusarium oxysporum</i> f. sp. <i>lycopersici</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Seed and soil treatment
Potato	Black scurf	<i>R. solani</i>	<i>Trichoderma viride</i>	Tuber treatment
Cauliflower	Damping off	<i>R. solani</i> , <i>P. aphanidermatum</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Seed and soil treatment
Cauliflower	Damping off	<i>R. solani</i> , <i>P. aphanidermatum</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Seed and soil treatment
<b>Fruit crops</b>				
Banana	Wilt (Panama disease)	<i>F. oxysporum</i> f. sp. <i>cabense</i>	<i>Trichoderma viride</i>	Soil and Rhizome treatment
Apple	White root rot	<i>Dematophora necatrix</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Soil treatment
Citrus group	Root rot	<i>Phytophthora nicotianae</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i> , <i>T. virens</i>	Soil treatment
Guava	Anthracnose	<i>Colletotrichum gloeosporioides</i> , <i>Pestalotia psidii</i>	<i>Trichoderma harzianum</i>	Foliar spray
	Wilt	<i>Fusarium oxysporum</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Soil treatment
Mango	Fruit rot	<i>Lasiodiplodia theobromae</i> , <i>Rhizopus arrhinus</i>	<i>Trichoderma</i> spp.	Fruit treatment
Orange	Blue mould	<i>Penicillium italicum</i>	<i>Trichoderma harzianum</i>	Fruit dip
<b>Cereal crops</b>				
Rice	Kernel smut	<i>Tilletia barclayana</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i> , <i>T. virens</i>	Seed/ soil/ seedling treatment
	Bunt	<i>Neovossia indica</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i> , <i>T. virens</i>	Seed treatment
	Sheath blight	<i>Rhizoctonia solani</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i> , <i>T. virens</i>	Seed, soil, seedling treatment and foliar spray
Maize	Brown spot	<i>Drechslera oryzae</i>	<i>Trichoderma viride</i>	Seed treatment
	Charcoal rot, Banded blight	<i>Macrophomina phaseolina</i> , <i>R. solani</i>	<i>Trichoderma</i> spp.	Seed treatment and foliar spray
Wheat	Root rot	<i>Sclerotium rolfsii</i> , <i>Fusarium oxysporum</i>	<i>Trichoderma harzianum</i>	Seed and soil treatment
	Loose smut	<i>Ustilago segatum tritici</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i> , <i>T. virens</i> , <i>T. lignorum</i> , <i>T. koningii</i>	Seed treatment
	Spot blotch	<i>Drechslera sorokiniana</i>	<i>Trichoderma viride</i> , <i>T. reesei</i> , <i>T. pseudokoningii</i>	Foliar spray
	Karnal bunt	<i>Neovossia indica</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i> , <i>T. virens</i> , <i>T. deliquescens</i> , <i>T. koningii</i>	Seed treatment

Crop Name	Disease Name	Causative agent	Effective <i>Trichoderma</i> spp.	Mode of application
Barley	Foot and root rot	<i>Fusarium</i> , <i>Sclerotium rolfsii</i> , <i>Curvularia</i> , <i>Pythium</i> , <i>Penicillium</i> , <i>Aspergillus</i>	<i>Trichoderma viride</i> , <i>T. pseudokoningii</i>	Seed treatment
<u>Pulse crops</u>				
Mung bean	Root rot	<i>Macrophomina phaseolina</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Seed and soil treatment
Pigeon pea	Wilt	<i>Fusarium udum</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i> , <i>T. koningii</i>	Seed and soil treatment
Chickpea	Seed borne diseases	<i>Alternaria alternata</i> , <i>Curvularia lunata</i>	<i>Trichoderma viride</i>	Seed treatment
	Wilt, seed and root rot	<i>Fusarium oxysporum</i> f. sp. <i>ciceris</i> , <i>R. bataticola</i> , <i>Pythium</i> sp.	<i>Trichoderma harzianum</i>	Seed and soil treatment
	Grey mould	<i>Botrytis cineria</i>	<i>Trichoderma</i> spp.	Foliar spray
Moth bean	Stem rot	<i>Sclerotinia sclerotiorum</i>	<i>Trichoderma harzianum</i>	Seed treatment
	Blight	<i>Macrophomina phaseolina</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Foliar spray
Cowpea	Wilt	<i>F. oxysporum</i> f. sp. <i>ciceris</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Seed and soil treatment
	Charcoal rot	<i>Macrophomina phaseolina</i> ,	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Seed and soil treatment
Lentil	Wilt complex, Collar rot	<i>R. solani</i> , <i>F. oxysporum</i> , <i>S. rolfsii</i>	<i>Trichoderma virens</i> , <i>T. viride</i> , <i>T. harzianum</i>	Seed and soil treatment
<u>Oilseed crops</u>				
Groundnut	Collar/ root/ crown/ stem/ pod rot	<i>Aspergillus flavus</i> , <i>S. rolfsii</i> , <i>A. niger</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Soil treatment
	Leaf rust	<i>Puccinia arachidis</i>	<i>Trichoderma harzianum</i>	Foliar spray
	Wilt complex, seed and root rots, stem rot	<i>Sclerotium rolfsii</i> , <i>F. solani</i> , <i>F. oxysporum</i> , <i>R. solani</i> ,	<i>Trichoderma viride</i> , <i>T. harzianum</i> , <i>T. virens</i>	Soil treatment
Mustard	Damping off	<i>Pythium aphanidermatum</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Seed and soil treatment
Safflower	Root rot	<i>Macrophomina phaseolina</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Seed and soil treatment
Sunflower	Blight	<i>Alternaria helianthii</i>	<i>Trichoderma virens</i>	Seed treatment
	Root rot, collar rot	<i>Sclerotium rolfsii</i> , <i>R. solani</i> , <i>Sclerotinia sclerotiorum</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Seed treatment
Sesamum	Blight	<i>Phytophthora</i> sp.	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Seed treatment
	Root rot	<i>Macrophomina phaseolina</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Seed and soil treatment
<u>Spices crops</u>				
Pepper	Collar rot	<i>Phytophthora capsici</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Soil treatment, Drenching
Cardamum	Damping off	<i>F. moniliformae</i> , <i>Pythium vexans</i> , <i>P. aphanidermatum</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Soil treatment, Drenching
	Capsule rot	<i>Phytophthora meadii</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Soil treatment

Crop Name	Disease Name	Causative agent	Effective <i>Trichoderma</i> spp.	Mode of application
Coriander	Wilt	<i>Fusarium oxysporum</i> f. sp. <i>corianderii</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Seed and soil treatment
Ginger	Rhizome rot	<i>F. oxysporum</i> f. sp. <i>Zingiberi</i> , <i>Pythium myriotylum</i>	<i>T. harzianum</i> , <i>G. virens</i>	Rhizome treatment
<u>Cash crops</u>				
Cotton	Root rot	<i>Rhizoctonia</i> sp., <i>M. phaseolina</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Soil treatment
Sugarbeet	Damping off	<i>P. aphanidermatum</i>	<i>Trichoderma harzianum</i>	Seed and soil treatment
	Wilt and root rot	<i>S. rolfsii</i>	<i>Trichoderma harzianum</i>	Soil treatment
Sugarcane	Red rot	<i>Colletotrichum falcatum</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Soil treatment and spray
	Root rot, Seedling rot	<i>Pythium graminicola</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Soil treatment
	Wilt	<i>Fusarium moniliformae</i>	<i>Trichoderma viride</i> , <i>T. harzianum</i>	Soil treatment

includes more than 80 species that can be used to control phytopathogenic fungi. Among them; *T. harzianum*, *T. viride*, *T. hamatum*, *T. polysporum*, *T. pseudokoningii*, *T. deliquescens*, *T. aureoviride*, *T. koningii*, *T. lignorum*, *T. reesei*, *T. longibrachiatum* and *T. virens* (formerly *Gliocladium*

*virens*) are considered as most potential biocontrol agents. *Trichoderma* occurrence is worldwide and is commonly found associated with roots, soil and plant debris, forest humus and orchids. Some of the commercially existing bio-control products (Table 2) are also available in the market.

Table 2: List of some commercial formulations of *Trichoderma* used in management of crop diseases in India

Trade Name	<i>Trichoderma</i> strains/ species	Manufacturer
Bioderma	<i>Trichoderma viride</i> + <i>T. harzianum</i>	Biotech International Ltd., New Delhi, India
Bio-fit	<i>Trichoderma viride</i>	Ajay Biotech (India) Ltd., Pune, India
Biocon	<i>Trichoderma viride</i>	Tocklai Experimental Station Tea Research Association, Jorhat (Assam), India
Antagon TV	<i>Trichoderma viride</i>	Green Tech, Agro-products, Rajaji Road Coimbatore, India
Ecofit	<i>Trichoderma viride</i>	Hoechst and Schening Agro. Evo. Ltd. Mumbai, India
Funginil	<i>Trichoderma viride</i>	Crop Health Bioproduct Research Centre, Ghaziabad, Uttar Pradesh, India
Trichogourd	<i>Trichoderma viride</i>	Anu Biotech International Ltd., Bangalore, India
Defence SF	<i>Trichoderma viride</i>	Wockhrted Life Science Ltd., Mumbai, India
Ecoderma	<i>Trichoderma viride</i> + <i>T. harzianum</i>	Morgo Bio-control Pvt. Ltd., Bangalore, India
Tricon	<i>Trichoderma viride</i>	Green Max, India
Biogourd	<i>Trichoderma viride</i>	Krishi Rasayan Export Pvt. Ltd., Solan (HP), India
Trichostar	<i>Trichoderma harzianum</i>	Green Tech, Agro-products, Rajaji Road Coimbatore, India
Gliostar	<i>Trichoderma virens</i>	GBPUAT, Pantnagar, Uttarakhand, India
Monitor	<i>Trichoderma</i> spp.	Agricultural and Biotech Pvt. Ltd. Gujarat, Department of Plant Pathology, MPKV, Rahuri
Tricho-X	<i>Trichoderma viride</i>	Excel Industries Ltd., Mumbai, India
Trieco	<i>Trichoderma viride</i>	Ecosense labs, India

### Mode of Action

*Trichoderma* spp. are biocontrol agents and they effective against fungal pathogens causing diseases in plants. In general, it kills or inhibits (Figure 1) the growth of pathogen mainly through the three mechanisms as given under.



Figure 1: *In vitro* efficacy of *Trichoderma* against *Sclerotium rolfsii* in dual culture

1. **Antibiosis:** Liberation of an antibiotic like substances or other chemical metabolites by the antagonistic fungi *viz.* *Trichodermin*, *viridin* etc. that are harmful to the pathogen and inhibit or kill their growth.

2. **Competition:** It is a condition in which there is a suppression of one organism (target pathogen) as the two species struggle for limiting quantities of nutrients, oxygen, space or other requirements.

3. **Mycoparasitism/ Hyper-parasitism:** The mechanism of mycoparasitism/ hyper-parasitism includes different kind of interaction like coiling of hyphae around the target organism, penetration, production of haustoria and lysis of hyphae through secretion of intercellular lytic enzymes like glucanase, cellulase, chitinase, protease, lipase etc., which disintegrate the cell wall of pathogen.

### Methods of Application

1. **Soil Application:** 1-2 kg *Trichoderma* spp. (powder formulation) or 500-1000 ml (liquid formulation) is added in 25-50 kg farm yard manure (FYM). Mixed thoroughly, cover with jute bag/ sugarcane leaves/ paddy straw and kept for 2-3 week in shade for proper multiplication. Maintain moisture and mix the mixture in every 3-4 days intervals before broadcasting in the field. Maintain optimum moisture for better multiplication of *Trichoderma* formulations. Apply well decomposed *Trichoderma* based FYM to the field before 15 days of sowing. This mixture can be applied in furrow/ pit/ pot and at the time of transplanting/ sowing. This mixture is sufficient for one acre of land.

2. **Seed Biopriming:** Seed biopriming is treatment of seed with *Trichoderma* formulations (@ 5-10 g kg<sup>-1</sup> seed) and incubating under moist and warm conditions until just prior to radicle emergence. After radicle emergence sow the bioprimed seeds in the field. In bioprimed seeds, the germinating conidia of *Trichoderma* form a layer around the seeds. Such seeds tolerate adverse conditions of the soil better than the non-primed seeds. Seed biopriming is beneficial for tomato, brinjal, chickpea, soybean etc. crops.

3. **Seed Treatment:** Use of 8-10 g *Trichoderma* spp. (powder formulation 2×10<sup>6</sup> cfu g<sup>-1</sup>) with 50 ml of water (bigger seeds) while small seeds at the rate of 6-8 g for the treatment of one kg seed before sowing. Apply 5-10 ml *Trichoderma* spp. (liquid formulation) litre<sup>-1</sup> of cow dung slurry for treatment of one kg seed before sowing particularly for cereals, pulses and oilseeds. Shade dries the seeds for 20-30 minutes before sowing is essential. Seed treatment is highly effective against seed and soil borne diseases.

4. **Seed Material Treatment:** Apply at the rate of 8-10 g *Trichoderma* powder with one litre of water (30 minutes) for the treatment of seed material like sugarcane setts, banana suckers, turmeric, ginger rhizomes and potato tubers before sowing. Shade dries the seeds for 20-30 minutes before sowing is essential.

5. **Nursery Bed Treatment:** 500 g *Trichoderma* spp. (powder formulation) mix in 10-15 kg well decomposed FYM/ compost/ vermicompost and broadcast in a one-acre area at evening time and at proper moisture conditions. 5-10 ml litre<sup>-1</sup> of water *Trichoderma* spp. (liquid formulation) is sufficient for soil drenching.

6. **Cutting/ Seedling's Root Dip Application:** 20-25 g *Trichoderma* spp. (powder formulation) or 5-10 ml (liquid formulation) dissolves in one litre of water for about 30 minutes. Dip the cuttings and roots of seedlings in to this prepared suspension for half-an-hour and transplant immediately. Root dipping is effective against soil borne diseases.

7. **Foliar application:** 8-10 g litre<sup>-1</sup> of water *Trichoderma* spp. (powder formulation) or 3-5 ml litre<sup>-1</sup> of water (liquid formulation) sprays on diseased plants at cooler hours on 10-12 days intervals.

8. **Soil Drenching:** 1-2 kg *Trichoderma* formulation mix in 200 litre of water and drench the soil in one acre area or 8-10 g litre<sup>-1</sup> of water in soil in the nurseries from time to time. Maintain optimum soil moisture while applying.

9. **Horticultural Crops:** 50-100 g *Trichoderma* formulation mix in sufficient quantity of FYM/ compost/ vermicompost/ field soil and apply the mixture plant<sup>-1</sup> in effective root zone of fruit tree. Doses will change in depending upon age of the plant.

### Conclusion

*Trichoderma* strains decompose organic farm wastes, solubilize soil phosphorous and micronutrients, reclaim adverse soil, increases the absorption of nutrients, improve soil fertility and protects soil eco-system. It increases the rate and percentage of seed germination, roots and shoots growth

as well as built systemic resistance of plants to diseases and drought. It reduces the need for harsh and expensive chemical fungicides. *Trichoderma* strains play an important role in the bio-remediation of soil that are contaminated with pesticides. It is compatible with organic manures and bio-fertilizers. Hence, application of *Trichoderma* as prophylactic or curative measure is an efficient, reliable and eco-friendly measure which can control to diseases effectively and also useful for sustainable agriculture.

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