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TRICHODERMA SPP.: A BIO-CONTROL APPROACH FOR SUSTAINABLE DISEASE MANAGEMENT

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Agriculture is an indispensable part of any country to feed the millions of people but plant pathogens are the most important factors affecting the production of crops inflicting severe losses to agricultural products every year. To protect the crops from this huge yield loss recently, chemical pesticides are used. Long-term using of chemical pesticides contaminate water, cause atmosphere pollution, and sometimes leave harmful residues which can lead to development of certain resistant organisms. Due to the side effects of chemical pesticides, sustainable crop production through eco-friendly management is essentially required in the current scenario. In biological control, genus *Trichoderma* serves as one of the best bioagents, which is found to be effective against a wide range of soil-borne, seed-borne and foliar pathogens. This species of fungi has been considered to be very beneficial for different levels of life.

Keywords: *Trichoderma* strains, Mycoparasitism, Antibiosis, Competition, Bio-control agents

INTRODUCTION

Agriculture is critically important for ensuring food security, alleviating poverty and conserving the vital natural resource on which the world's present and future generation will be entirely dependent upon for their survival and wellbeing. Agricultural crops are vulnerable to attack number of pests like 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 cereals, oilseeds, pulses, vegetables, fibres and fruit crops, are seed and soil borne in nature. The continuous cultivation of a crop in the same piece of land resulted in heavy incidence of soil borne diseases due to build-up of a high inoculum of the pathogen. That forces the farmers to change either crop or land. Fungicides play an important role in management of seed borne and air borne 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 (pest) management (IDM) 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, Chaetomiam globosum, Ampelomyces* spp., *Candida* spp., and *Coniothyrium* spp. and bacterial agents like *Bacillus subtilis, B. cereus, Pseudomonas fluorescens, Agrobacterium radiobacter* etc. It has been reported to work nicely as antagonists against many fungal plant pathogens *in vitro* and *in vivo* conditions. Among

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these biocontrol agents *Trichoderma* spp. is one of the most versatile bio-control agents which has long been used for managing plant pathogenic fungi.

GENUS TRICHODERMA AND THEIR HABITATS:

Trichoderma is a fungal genus that was described in 1794, including anamorphic fungi isolated primarily from soil and decomposing organic matter (Persoon 1794). 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. In the early 1930s Trichoderma was introduced as possessing biocontrol ability (Weindling, 1934). Trichoderma is an opportunistic, avirulent plant symbiont fungus which acts as an antagonistic and parasitic fungus against many plant pathogenic fungi and offers protection from phytopathogenic plant diseases. 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* 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 available in the market are shown in table-2.

Mode of action: *Trichoderma* spp. are biocontrol agents, effective against fungal phytopathogens. The three most important antagonistic process of *Trichoderma* spp. include.

1. **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.
2. **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.
3. **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.

METHOD OF APPLICATION OF *TRICHODERMA* SPP.:

1. **Seed treatment:** Use of 8-10gram *Trichoderma* spp. (powder formulation $2x10^6$ cfu/g) with 50 ml of water (bigger seeds) while small seeds at the rate of 6-8 gram for the treatment of one kg seed before sowing. Apply 5-10 ml *Trichoderma* spp. (liquid formulation) per litre 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.
2. **Seed biopriming:** Seed biopriming is treatment of seed with *Trichoderma* formulations (@ 5-10 gram/kg 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. This technique has potential advantages over simple coating of seeds as it results in rapid and uniform seedling

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emergence. Seed biopriming is beneficial for tomato, brinjal, chickpea, soybean etc crops.

3. **Seed material treatment:** Apply at the rate of 8-10gram *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.
4. **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.
5. **Cutting/Seedling's root dip application:** 20-25gram *Trichoderma* spp. (powder formulation) or 5-10 ml (liquid formulation) dissolve in one litre of water for about 30 minutes. Dip the cuttings and roots of seedlings in to this prepared suspension for half an hours and transplant immediately. Root dipping is effective against soil borne diseases.
6. **Nursery bed treatment:** 500gram *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 of water *Trichoderma* spp. (liquid formulation) is sufficient for soil drenching.
7. **Soil drenching:** One-to-two-kilogram *Trichoderma* formulation mix in 200 litre of water and drench the soil in one acre area or 8-10 gm/litre of water in soil in the nurseries from time to time. Maintain optimum soil moisture while applying.
8. **Horticultural crops:** Fifty-to-hundred-gram *Trichoderma* formulation mix in sufficient quantity of FYM/compost/vermicompost/field soil and apply the mixture per plant in effective root zone of fruit tree. Doses will change in depending upon age of the plant.
9. **Foliar application:** 8-10 gram/litre of water *Trichoderma* spp. (powder formulation) or 3-5 ml/litre of water (liquid formulation) spray on diseased plants at cooler hours on 10-12 days intervals.

BENEFITS:

1. *Trichoderma* strains act against many plant pathogenic fungi (seed, soil-borne) and control the diseases by action of myco-parasitism and antibiosis.
2. *Trichoderma* strains decomposes organic farm wastes, solubilizes soil phosphorous and micronutrients, reclaims adverse soil, increases the absorption of nutrients, improve soil fertility and protects soil eco-system.
3. Reduces crop losses, increases plant growth, yield and source of income.
4. Reduces the need for harsh and expensive chemical fungicides.
5. It is compatible with organic manures and bio-fertilizers. like *Azospirillum*, *Rhizobiu*m, *Bacillus subtilis*, *Mycorrhizae*, phosphorus solubilizing bacteria and other bio-agents.
6. It increases the rate and percentage of seed germination, root and shoot growth as well as built systemic resistance of plants to diseases, pests and drought.
7. *Trichoderma* strains play an important role in the bio-remediation of soil that are contaminated with pesticides and herbicides. It has ability to breakdown the pesticides and herbicides residues in the soil. This process is called bio-remediation. Trichoderma spp. have the ability to degrade a wide range of insecticides groups like organochlorines, carbamates and organophosphates.
8. It is an eco-friendly, beneficial for environment, safe for users and farming communities. It is effective in organic farming for management of diseases.

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PRECAUTIONS IN USE OF *TRICHODERMA* FORMULATIONS:

1. Don't use chemical fungicide after application of *Trichoderma* formulation for 4-5 days.
2. Don't use *Trichoderma* in dry soil, moisture is essential for its growth and survivability.
3. Do not keep *Trichoderma* treated seeds in direct sun light.
4. Don't put the treated FYM for a longer duration.
5. Do not use *Trichoderma* formulation without organic manure or slurry.

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Table 1: Disease management through *Trichoderma* spp.

Crop Name	Disease Name	Causative agent	Effective *Trichoderma* spp.	Mode of application
Cereal crops				
Rice	Sheath blight	*Rhizoctonia solani*	*Trichoderma viride, T. harzianum, T. virens*	Seed, soil, seedling treatment and foliar spray
	Brown spot	*Drechslera oryzae*	*Trichoderma viride*	Seed treatment
	Bunt	*Neovossia indica*	*Trichoderma viride, T. harzianum, T. virens*	Seed treatment
	Kernel smut	*Tilletia barclayana*	*Trichoderma viride, T. harzianum, T. virens*	Seed, soil, seedling treatment
Barley	Foot and root rot	*Sclerotium rolfsii, Fusarium, Curvularia, Pythium, Penicillium, Aspergillus*	*Trichoderma viride, T. pseudokoningii*	Seed treatment
Wheat	Root rot	*Sclerotium rolfsii, Fusarium oxysporum*	*Trichoderma harzianum*	Seed and soil treatment
	Loose smut	*Ustilago segatum tritici*	*Trichoderma viride, T. harzianum, T. virens, T. lignorum, T. koningii*	Seed treatment
	Spot blotch	*Drechslera sorokiniana*	*Trichoderma viride, T. reesei, T. pseudokoningii*	Foliar spray
	Take-all	*Gaeumanomyces graminis var. tritici*	*Trichoderma harzianum*	Seed treatment
	Karnal bunt	*Neovossia indica*	*Trichoderma viride, T. harzianum, T. virens, T. deliquescens, T. koningii*	Seed treatment
Maize	Charcoal rot, Banded blight	*Macrophomina phaseolina, R. solani*	*Trichoderma* spp.	Seed treatment and foliar spray

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Pulse crops				
Chickpea	Wilt, seed rot, root rot	*Fusarium oxysporum* f. sp. *ciceris, R. bataticola, Pyhtium sp.*	*Trichoderma harzianum*	Seed and soil treatment
	Grey mould	*Botrytis cineria*	*Trichoderma* spp.	Foliar spray
	Stem rot	*Sclerotinia sclerotiorum*	*Trichoderma harzianum*	Seed treatment
Pigeon pea	Wilt	*Fusarium udum*	*Trichoderma viride, T. harzianum, T. koningii*	Seed and soil treatment
	Seed borne diseases	*Alternaria alternata, Curvularia lunata*	*Trichoderma viride*	Seed treatment
Mung bean	Root rot	*Macrophomina phaseolina*	*Trichoderma viride, T. harzianum*	Seed and soil treatment
Lentil	Wilt complex, Collar rot	*R. solani, F. oxysporum, S. rolfsii*	*Trichoderma virens, T. viride, T. harzianum*	Seed and soil treatment
Cowpea	Wilt	*F. oxysporum* f. sp. *ciceris*	*Trichoderma viride, T. harzianum*	Seed and soil treatment
	Charcoal rot	*Macrophomina phaseolina,*	*Trichoderma viride, T. harzianum*	Seed and soil treatment
Moth bean	Blight	*Macrophomina phaseolina,*	*Trichoderma viride, T. harzianum*	Foliar spray
Oilseed crops				
Mustard	Damping off	*Pythium aphanidermatum*	*Trichoderma viride, T. harzianum*	Seed and soil treatment
Sesamum	Blight	*Phytophthora sp.*	*Trichoderma viride, T. harzianum*	Seed treatment
	Root rot	*Macrophomina phaseolina*	*Trichoderma viride, T. harzianum*	Seed and soil treatment
Safflower	Root rot	*Macrophomina phaseolina*	*Trichoderma viride, T. harzianum*	Seed and soil treatment
Sunflower	Blight	*Alternaria helianthii*	*Trichoderma virens*	Seed treatment
	Root rot, collar rot	*Sclerotium rolfsii, R. solani, Sclerotinia sclerotiorum*	*Trichoderma viride, T. harzianum*	Seed treatment
Groungnut	Wilt complex, seed rot, root rot, stem rot	*Sclerotium rolfsii, F. solani, F. oxysporum, R. solani,*	*Trichoderma viride, T. harzianum, T. virens*	Soil treatment
	Leaf rust	*Puccinia arachidis*	*Trichoderma harzianum*	Foliar spray
	Collar/root/crown/stem/pod rot	*Aspergillus flavus, S. rolfsii, A. niger*	*Trichoderma viride, T. harzianum*	Soil treatment

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Fruit crops				
Mango	Fruit rot	*Lasiodiplodia theobromae, Rhizopus arrhinus*	*Trichoderma* spp.	Fruit treatment
Apple	White root rot	*Dematophora necatrix*	*Trichoderma viride, T. harzianum*	Soil treatment
Citrus group	Root rot	*Phytophthora nicotianae*	*Trichoderma viride, T. harzianum, T. virens*	Soil treatment
Banana	Wilt (Panama disease)	*F. oxysporum* f. sp. *cubense*	*Trichoderma viride*	Soil and Rhizome treatment
Orange	Blue mould	*Penicillium italicum*	*Trichoderma harzianum*	Fruit dip
Guava	Antharcnose	*Colletotrichum gloeosporioides, Pestalotia psidii*	*Trichoderma harzianum*	Foliar spray
	Wilt	*Fusarium oxysporum*	*Trichoderma viride, T. harzianum*	Soil treatment
Vegetable crops				
Tomato	Damping off	*Pythium indicum*	*Trichoderma viride, T. harzianum*	Seed and soil treatment
	Seedling wilt	*Fusarium oxysporum* f. sp. *lycopersici*	*Trichoderma viride, T. harzianum*	Seed and soil treatment
Potato	Black scurf	*R. solani*	*Trichoderma viride*	Tuber treatment
Brinjal	Wilt, damping off	*F. solani, P. aphanidermatum*	*Trichoderma viride, T. harzianum, T. virens*	Seed and soil treatment
	Collar rot	*Sclerotinia sclerotiorum*	*Trichoderma viride, T. virens*	Soil treatment
Chilli	Root rot	*Sclerotium rolfsii*	*Trichoderma harzianum, T. viride*	Soil treatment
Radish	Seedling rot, damping off, seed rot	*Pythium sp., R. solani*	*Trichoderma harzianum, T. hamatum*	Seed treatment
Pea	Seed and collar rot	*Pythium sp., R. solani*	*Trichoderma harzianum, T. hamatum*	Seed treatment
	Wilt	*Fusarium oxysporum f. sp. pisi*	*Trichoderma harzianum, T. viride*	Soil treatment
Cauliflower	Damping off	*R. solani, P. aphanidermatum*	*Trichoderma viride, T. harzianum*	Seed and soil treatment
Cabbage	Damping off	*R. solani*	*Trichoderma harzianum, T. viride*	Seed treatment
Bean	Seedling rot	*Pythium sp., S. sclerotiorum, R. solani, B. cineria*	*Trichoderma koningii*	Seed treatment
Plantation crops				

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Rubber	Brown rot	*Phellinus noxius*	*Trichoderma viride, T. harzianum, T. hamatum*	Soil treatment
Coffee	Collar rot	*R. solani*	*Trichoderma harzianum*	Seed and soil treatment
Mulberry	Cutting rot	*Fusarium solani*	*Trichoderma viride, T. virens, T. pseudokoningii*	Cutting and soil treatment
	Stem canker, die back	*Botryodiplodia spp.*	*Trichoderma viride, T. virens, T. pseudokoningii*	Cutting and soil treatment
Cash crops				
Sugarcane	Red rot	*Colletotrichum falcatum*	*Trichoderma viride, T. harzianum*	Soil treatment and spray
	Root rot, Seedling rot	*Pythium graminicola*	*Trichoderma viride, T. harzianum*	Soil treatment
	Wilt	*Fusarium monilifomae*	*Trichoderma viride, T. harzianum, T. longibrachiatum*	Sett treatment
Sugarbeet	Damping off	*P. aphanidermatum*	*Trichoderma harzianum*	Seed and soil treatment
	Wilt and root rot	*S. rolfsii*	*Trichoderma harzianum*	Soil treatment
Cotton	Root rot	*Rhizoctonia sp., M. phaseolina*	*Trichoderma viride, T. harzianum*	Soil treatment
Spices crops				
Ginger	Rhizome rot	*F. oxysporum* f. sp. *Zingiberi, Pythium myriotylum, F. solani*	*T. harzianum, G. virens*	Rhizome treatment
Coriander	Wilt	*Fusarium oxysporum* f. sp. *corianderii*	*Trichoderma viride, T. harzianum*	Seed and soil treatment
Pepper	Collar rot	*Phytophthora capsici*	*Trichoderma viride, T. harzianum*	Soil treatment, Dernching
Cardamum	Damping off	*F. moniliformae, Pythium vexans, P. aphanidermatum*	*Trichoderma viride, T. harzianum*	Soil treatment, Dernching
	Capsule rot	*Phytophthora meadii*	*Trichoderma viride, T. harzianum*	Soil treatment

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Table 2: Common commercial *Trichoderma* formulation used in India.

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