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Mechanism of *Trichoderma* Spp. and Their Role in Biological Management of Plant Diseases

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Abstract

Trichoderma is a fungal micro-organism that has been used as a bio-agent against various soil and seed-borne plant diseases worldwide. *Trichoderma* has various antifungal properties such as mycoparasitism, antibiotics production, competition for food and space as a direct mechanism against phytopathogens that help to reduce the pathogenic activities or populations. Indirect mechanisms of *Trichoderma* such as plant root colonization, bio-fertilization, Induce systemic resistance in the host plant, resistance to pesticides, and growth promoter help to make harder of the host against the pathogen. Therefore both direct and indirect mechanisms of *Trichoderma* are effective to overcome many plant diseases. *Trichoderma* is generally available in the market as a powder-based formulation, it used as a seed or soil treatment and also seedling dip. The foliar spray used in the case of foliar disease management.

Introduction

Trichoderma is a genus of soil-dwelling fungi found all over the world that is highly effective at colonizing many kinds of plant roots and inhibiting fungi that cause many types of diseases. It was one of the first types of bio-fungicides commercially available.

Trichoderma spp. have been extensively studied, are among the microorganisms most commonly used as biological control agents, and are presently marketed as active ingredients of bio-pesticides, bio-fertilizers, growth enhancers and stimulants of natural resistance. This is due to their ability to protect plants, enhance vegetative growth and contain pathogen populations under numerous agricultural conditions, as well as to act as soil amendments/ inoculants for improvement of nutrient ability, decomposition, and biodegradation.

Trichoderma can direct antagonism of pathogenic fungi by competition, antibiotics, and direct attack with hydrolytic enzymes. Especially, some isolates of *Trichoderma* are well-identified bio-control agents, having the capacity to function against a broad spectrum of fungal pathogens including *Botrytis cinerea*, *Rhizoctonia solani*, *Sclerotinia sclerotiorum*, *Sclerotium* spp, *Pythium ultimum*, *Phytophthora* spp, *Armillaria* spp, *Fusarium oxysporum*, *Verticillium* spp, *Macrophomina phaseolina*, and *Gauemannomyces graminis*.

The species most commonly used in bio-control include *T. harzianum*, *T. atroviride*, *T. asperellum*, *T. polysporum* and, *T.viride*, etc. The antagonistic potential serves as the basis for effective biological control applications of different Trichoderma strains as bio-fungicides against soil, foliar and vascular pathogens, as another to chemical pesticides for treatment against a wide spectrum of plant pathogens, as well as to increase resistance to abiotic stresses.

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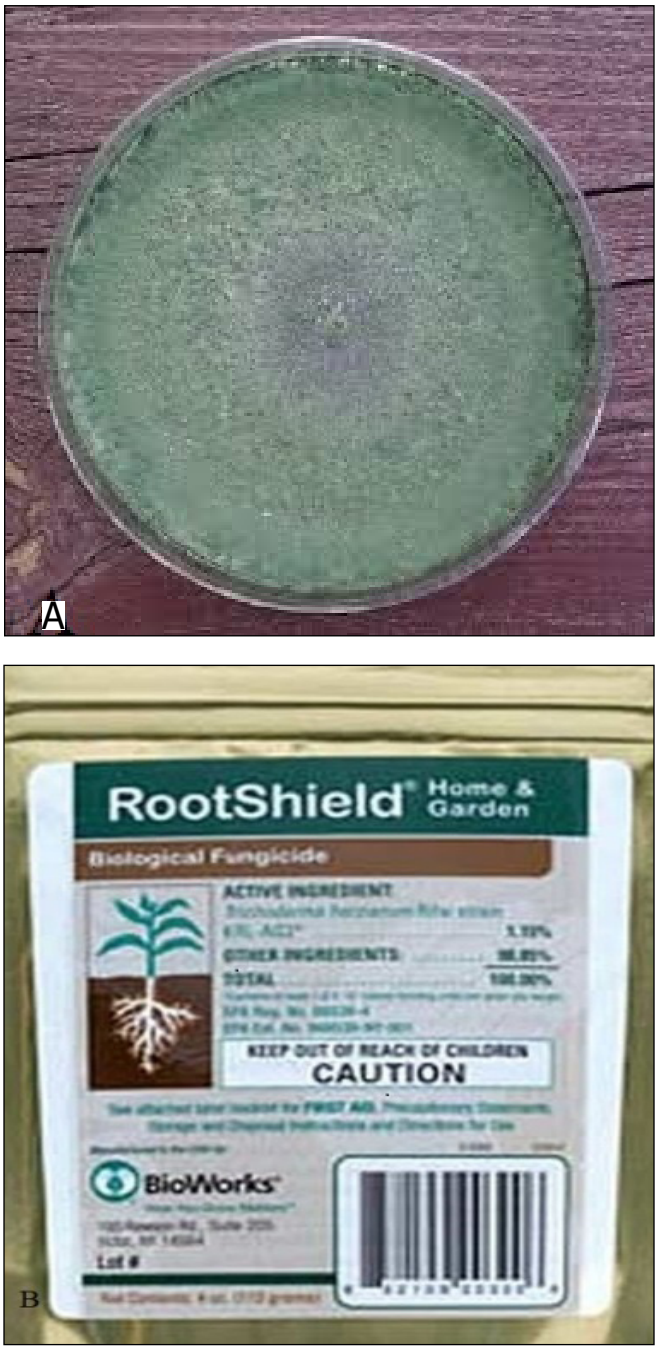

Figure 1: Trichoderma Culture (A), Commercial Product of Trichoderma (B)

Molecular Mechanisms of Action of *Trichoderma*

Antagonist interacts with pathogen and host in soils either directly or indirectly. In indirect interactions plant responds to the presence of the antagonist, resulting in induced resistance or plant growth promotion. Based on the interaction, the mechanism of action may be direct or indirect.

A. Direct Mechanism of Action

a) Mycoparasitism

Mycoparasitism is a complex process, involving the tropic growth of the bio-control agent towards the target organism and coiling, and finally dissolved of the target organism's cell wall/ cell membrane through the enzymatic activity of chitinase, glucanase, and pectinase.

Trichoderma may grow attached with hyphae of target pathogen, form haustoria, which may penetrate host fungal cells to draw nutrients. For example, the same isolate of *Trichoderma harzianum*, against *R. solani*, may show both coiling and haustoria formation.

b) Antibiotic Production

Antibiosis is the process of secretion of antimicrobial compounds by antagonistic fungi to suppress and/or kill pathogenic fungi in the vicinity of its growth area. *Trichoderma* strains are known to produce antibiotics and toxins.

It produces antibiotics and toxins such as trichothecene and a sesquiterpene, Trichodermin, which have a direct effect on other organisms. Examples of such chemicals are Trichothecin, Trichodermin, etc.

c) Competition

It is the phenomenon in which *Trichoderma* suppresses the pathogen population in the rhizosphere through competition with pathogenic microorganisms for space and nutrients, and reduces disease development. For example, *Trichoderma harzianum* suppressed the infestation of *Macrophomina phaseolina* (dry root rot of mungbean) of mungbean by soil application as well as a seed treatment *in vivo* (Kumar *et al*., 2020).

d) Inactivation of the Pathogen's Enzymes

This is another bio-control mechanism of *Trichoderma* in which various enzymes Chitinases, glucanases, and other hydrolytic enzymes have many roles in a wide range of different biological systems. These enzymes are usually extracellular, of low molecular weight, and highly stable. These enzymes are an effective tool for the inactivation of the pathogen's enzymes and also help to complete the destruction of mycelia walls of phytopathogenic fungi.

B. Indirect Mechanism of Action

a) Plant Root Colonization

Once in the soil, this fungus colonizes the roots of plants. By growing on the roots and in the rhizosphere, it forms a physical barrier to prevent the growth of fungi that would otherwise cause disease on the plant.

Plants commonly produce chemicals to defend themselves, and *Trichoderma* is resistant to many of them, which helps it

to colonize the roots. And it does this without interfering with other microbes that help the plants, such as mycorrhizae or Rhizobium (bacteria that fix nitrogen).

Trichoderma strains must colonize plant roots prior to stimulation of plant growth and protection against infections. *Trichoderma* secretes various enzymes Chitinases, glucanases, and other hydrolytic enzymes that help to complete degradation of mycelia or conidial walls of phytopathogenic fungi.

b) Bio-fertilization

Trichoderma can improve plant health even in the absence of pathogens. The fungus grows best in soil that is acidic, and it helps create such an environment by secreting organic acids.

These acids have an additional effect that greatly benefits the plants – they can solubilize phosphates and mineral ions, such as iron, magnesium, and manganese. These means they facilitate the dissolving of these minerals, making it easier for the plants to absorb them. Such nutrients are often in short supply in the soil.

c) Resistance to Pesticides

Many strains of *Trichoderma* are unusually resistant to toxic compounds, ranging from pesticides to chemicals produced by plants. Its pesticide resistance includes herbicides, fungicides, and insecticides like DDT.

This gives an edge to using these fungi to control pathogens since you can alternate the application of strain T-22 with fungicides like benomyl or captan.

d) Simulation of Plant Defense Mechanism

Trichoderma strains are known to induce resistance in plants, that reduced susceptibility to pathogen attack in the instance of induce systemic acquired resistance (ISR) activated molecular such as enzymes, proteins, secondary metabolites that produce the systemic induced resistance in host plants through ethylene production, hypersensitive responses and other defense-related reactions in the plant. *Trichoderma* also plays a vital role in enhanced resistance against abiotic stresses such as drought, salinity, nutrients, etc.

e) Growth Promoter

Trichoderma enhances yield along with the quality of products and increases the germination rate. Increase in shoot & root length, solubilizing various insoluble forms of phosphates, augment nitrogen-fixing, promote healthy growth in early stages of the crop, increase dry matter and, provide natural long term immunity to crops and soil. Hances yield along with the quality of products and increase the germination rate. Increase in shoot & root length, solubilizing various insoluble forms of phosphates, augment nitrogen-fixing, promote healthy growth in early stages of the crop, increase dry matter and, provide natural long term immunity to crops and soil.

f) Competitive Saprophytic Ability

Trichoderma is capable of decomposition the organic matter within a short period of time. *Trichoderma* is having a high competitive saprophytic ability. Hence, the plant pathogens could not able to compete with this bioagents, and ultimately results in less disease development. The competitive saprophytic ability could help for microbial disease management.

Benefits and Uses of *Trichoderma*

1. Plant Disease Control

A number of plant diseases caused by fungi can be potentially controlled by *Trichoderma harzianum* based formulations. It is very effective under different climatic conditions in various crops including cereals, pulses, vegetables, spices, etc. to control various fungal diseases.

The application of *Trichoderma* species can control a large number of foliar and soil-borne fungi i.e. *Fusarium* spp., *Pythium* spp., *R. solani*, *Sclerotium rolfsii*, in vegetables, field, fruit, and industrial crops. Therefore, farmers have reduced their use of chemical fungicides.

2. Abiotic Stress Resistant

Trichoderma develops abiotic stress resistance in plants by increasing the root length, the thickness of plant cells, and, the surface area for uptake of nutrients and water from the soil.

3. Transgenic Plants

Introduction of the endochitinase gene from *Trichoderma* into plants such as tobacco and potato plants has increased their resistance to fungal growth. Selected transgenic lines are highly tolerant of foliar pathogens such as *Alternaria alternata*, *A. solani*, and *Botrytis cinerea* as well as to the soil-borne pathogen, *Rhizoctonia solani*.

4. Bioremediation

Trichoderma strains play an important role in the bioremediation of soil that is contaminated with pesticides and herbicides. They have the ability to degrade a wide range of insecticides like organochlorines, organophosphate, and carbonates, etc.

5. Resistance to Pesticides

Trichoderma strains play an important role in the bioremediation of soil that are contaminated with pesticides and herbicides residues. They have the ability to degrade a wide range of insecticides like organochlorines, organophosphates and carbonates etc.

6. Trichoderma Formulations

The living bio-agent can be incorporated into various formulations as pure spores or conidia suspensions, in liquid culture filtrates, and can be integrated with various inert components and stored for months without

losing efficacy.

Important commercial formulations are available in the name of Sanjeevni, Bioveer, Ecoderma and, Root Shield, etc. These formulations contain 3×10^6 cfu per 1 g of a carrier material. Talc is used as a carrier for making powder formulation.

How to Use *Trichoderma* Formulation in Field

The formulations are applied as a foliar spray, pre-planting application to seed or propagation material, post-pruning treatment, incorporation in the soil during seeding or transplant, watered by irrigation, or applied as a root dip or drench. The products are used in the greenhouse, nursery, field, orchards as well as in hydroponics. Until now, *Trichoderma* -based preparations are commercialized worldwide and used for crop protection from various plant pathogens or to increase the plant growth and productivity in a variety of fields, greenhouses, nurseries, horticultural, fruits, trees, and ornamental crops.

Prior soil application, Trichoderma powder well mixed with well rotten farmyard manure, keep the mixture moist with the help of frequently water sprinkle and covered with moist gunny bags under shade condition. Keep this until the whole mixture gets full of *Trichoderma* mycelium growth. In this process, the dormant spore of *Trichoderma* gets active. This above mention process is given a more effective result than normal soil application.

Table 1: Trade Name of Commercial Products of Trichoderma formulation and their role in disease management

S.No	Trade name	Active Substances	pests
1.	Bioveer	*T. viride*	Root rot, Foot rot, collar rot, stem rot, damping off, wilt, blight/leaf spot; sheath rot, sheath blight and bacterial leaf blight of rice.
2.	Biovidi	*T. viride*	
3.	Coimbatore	*T. viride*	Prevents the crops from diseases such as Root rots, Wilts, brown rot, damping off, Charcoal rot and other soil born diseases in crops.
4.	Commander	*T. harzianum*	Soil Nematode, Fusarium Wilt & Blister Blight.
5.	Ecoderma	*T. viride*	-
6.	Sanjeevni	*T. viride*	Fusarium, Rhizoctinia, sclerotium, Verticillium, Macrophomina, Alternaria, Helminthosporium, Pythium, Phytopthora etc.
7.	Tricho Shield Combat	*T. viride*	Bio-management of soil borne fungal infections of crops
8.	Root-Pro	*T. harzianum* T-35 + *T. harzianum* T-315	Control of soil-borne diseases Pythium spp., Sclerotium rolfsi, Fusarium spp., Rhizoctonia solani
9.	Root Shield	*T. harzianum* Rifai strain T- 22 (KRL-AG2)	Root disease control Fusarium, Pythium, Rhizoctonia, Thielaviopsis and Phytophthora , Pythium.
10.	Trichodermas Bio-lower	*T. harzianum*	Diverse root pathogenic fungi (Rhizoctonia, Fusarium, Pythium, etc)

Precautions

- Don't use chemical fungicide after the application of *Trichoderma* for 4-5 days.
- Don't use *Trichoderma* in dry soil. Moisture is an essential factor for its growth and survivability.
- Don't keep the treated FYM for a longer duration.
- Don't put the treated seeds in direct sun rays.
- Don't use *Trichoderma* formulation without organic manure or slurry.

Compatibility

- *Trichoderma* is compatible with organic manures, bio-fertilizers like *Rhizobium*, *Azospirillum*, *Mycorrhizae*, *Azotobacter*, *Bacillus subtilis,* and phosphorus solubilizing bacteria and other bio-agents.
- *Trichoderma* can be applied to seeds treated with captan, metalaxyl, carboxin, carbendazim.
- Don't compatible with mercurial's group of fungicides.

Conclusion

Trichoderma plays an important role in controlling fungal pathogens especially soil-borne pathogens. The use of *Trichoderma* has the most important bioagents in managing several plant diseases. Antagonist microorganisms, such as *Trichoderma*, reduce growth, survival, or infections caused by pathogens by different mechanisms like competition, antibiosis, mycoparasitism, hyphal interactions, and enzyme

secretion, etc. The technique for mass production and the use of these bio-agents has been commercialized for producers and farmers. *Trichoderma* minimizing the fungicidal hazards that adverse effect on human health and our ecosystem. Biological weapon helps to provide eco-friendly and cost-effective disease management.

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