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Trichoderma: A Unique Bio-control Agent Boost up Plants Immunity

Amar Bahadur

Plant Pathology, College of Agriculture, Agartala, India

Email address:
amarpatel44@rediffmail.com

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Abstract: Climate changes are responsible for the emergence of new diseases and pests that affect agricultural production. Crops diseases and pests are a threat to agricultural crop production that affect yield in quantity and quality. Plant pathogenic fungi, bacteria, viruses and nematodes are affecting the growth of plants and reducing their yields. *Trichoderma* spp. is well known biological control agent, which is widely used in agricultural crop production. *Trichoderma* is one of the beneficial bio-agent which influences soil health and acts as a bio-fertilizer, bioremediation, uptake of nutrients, plant growth promoter, resistance to abiotic stresses, and increases crops yield. *Trichoderma* spp. is colonization in the roots that helps insolubilization of minerals such as Zn, Cu, Fe, Mn, rock phosphate, and N-used efficiency. It's widely studied due to its production of antibiotics that parasitize other fungi and compete with harmful plant microbes as common in soil and root inhabitants. Mechanisms involved as production of antibiotics, competition for nutrients, mycoparasitism, and systemic induce resistance in plants. *Trichoderma* spp. can manage plant diseases in the sustainable agricultural crop production and detoxification of polluted areas. In the rhizosphere zone their recognition and exchange of signalling molecules by *Trichoderma.* In association with plant roots, triggers systemic induce resistance and increases plant nutrient uptake. *Trichoderma* enhances plant growth, development and resistance that increased the yield of crops. Induce root branching and increase shoot biomass by *Trichoderma* strains is due to fungal auxin-like compounds. *Trichoderma* spp is effective against soil-borne plant pathogenic fungi and nematodes also. *Trichoderma* spp is one of the fast-growing bio-control agents that produce green spores as chlamydospores and is used against soil-borne plant pathogens such as *Sclerotium rolfsii, Rhizoctonia solani, Fusarium, Macrophomina, Pythium, Phytophthora*, and *Aspergillus*, manage through the action of mycoparasitism, antibiotics and competition for food and space. *Trichoderma* is a beneficial organism in an ecological situation and environmental compatibility makes it useful in all types of cropping systems in agriculture and food safety. *Trichoderma* can manage plant-parasitic nematodes by inducing resistance, parasitism, antibiosis, production of lytic enzymes, and modifying the root, nutrient and water uptake by the plants.

Keywords: *Trichoderma*, Mechanism, Application, Management

1. Introduction

Trichoderma spp is recognized as a biological agent and its ability to increase root growth and development, uptake and use of nutrients, resistance to abiotic stresses and control of plant disease. Their mechanisms depend on environmental conditions such as temperature, pH, nutrient concentrations and type of fungus [1]. The ability of *Trichoderma* to colonize in the rhizosphere and take up nutrients from the soil. Competition for nutrients such as carbon, nitrogen and space [2]. Through the competition of nutrients, *T. harzianum*t can control *Fusarium oxysporum* f. sp. *melonis* [3]. Some strains of *Trichoderma* produce siderophores as a chelate of iron and stop the growth of fungi [4]. The use of chemical pesticides in long term can lead to the development of resistance in organisms [5]. *Trichoderma* spp is an alternative bio-control agent, which is safe and suppresses the growth of plant pathogens in an eco-friendly [6]. *Trichoderma* is a fungus, which is widely distributed in the soil, decaying vegetation, plant material and wood [1]. *Trichoderma* strains also play an important role in the bioremediation of soil contaminated by pesticides and herbicides. [7]. *Trichoderma* can produce hydrolytic enzymes

like cellulases and chitinases, which are resistant to a wide range of toxicants, heavy metals and harmful chemicals [8]. *Trichoderma* spp. accumulates and removes various heavy metals such as copper, zinc, cadmium, and arsenic through volatilization [9-11]. *T. harzianum* mutants released higher levels of lytic enzymes, chitinases and cellulases [12-14]. Mycoparasitism is a complex process of the growth of the bio-control agent towards the targeted fungi by lectin-mediated coiling of *Trichoderma* hyphae. Secondary metabolites compounds of *Trichoderma* spp. have played a key role in mycoparasitism [15]. Through the mycoparasitic activity *Trichoderma* attack and lyse plant pathogenic fungi such as *Rhizoctonia solani, Sclerotinia sclerotiorum, Alternaria alternata, Botrytis cinerea, Fusarium* spp. and *Pythium* spp. [16]. *Trichoderma* can activate systemic resistance in plants. *Trichoderma* was first described as a genus in Germany [17]. Colonies characteristics such as growth pattern, growth rate, odor, and color that used to identification of *Trichoderma* [18]. Coconut odor present in the soil is due to the volatile 6-pentyl-a-pyrone [19-21]. *Trichoderma harzianum* occurs in warm climates and *Trichoderma viride* in cool temperature regions, more prevalent in acidic soils. The production of siderophores, phosphate-solubilizing enzymes, and phytohormones by *Trichoderma* spp. can category of plant growth-promoting fungi [22]. *Trichoderma* spp. help in plant growth promotion including mycoparasitism, degradation of toxins, antibiosis, pathogenic enzymatic inactivation, nutrients enhancement, resistance to pathogens, solubilization of inorganic nutrients and root hair development [23]. Induced phenolic compounds in plants can be led to the enhancement of seed vigor. *Trichoderma* is known to accumulate heavy metals, namely, copper, cadmium, zinc, and arsenic [11, 24].

2. *Trichoderma* spp

Trichoderma common species are *Trichoderma viride. Trichoderma harzianum, Trichoderma koningii, Trichoderma longibrachiatum, Trichoderma pseudokoningii, Trichoderma hamatum, Trichoderma polysporum,* and *Trichoderma viren. Trichoderma* is an excellent bio-control agent with a high ability to multiply, spread, easy to isolate and culture. *Trichoderma* has more than 100 species that belong to the order-Hypocreales, family-Hypocreaceae [7]. *Trichoderma* belongs to the ascomycete and their teleomorphs are Hypocrea Fr. *Trichoderma* used against *Pythium, Phytophthora, Botrytis, Rhizoctonia,* and *Fusarium* manage through the competition for nutrients and space, antibiosis, induction of plant defensive mechanisms and mycoparasitism [25]. *Trichoderma* can be identified based on the morphology and colour of the colonies on the potato dextrose agar medium and a characteristic 'coconut' odor produced by some species. Identification was confirmed based on the morphology of the conidia and conidiophores of different *Trichoderma* species. Based on morphological is a primary method of identification and cannot differentiate diversity between species. *Trichoderma* is fast growing fungus with an optimum temperature range between 25-30°C. All primary and secondary branches arise at or near 90° to the main axis of *Trichoderma* species. Chlamydospores may be produced by all species. Treated seed by *Trichoderma* spp. releases metabolite (gliotoxin) that initiates plant growth hormone, enhances seed generation percentage, activate enzymes and phytohormones. The ability of *Trichoderma* to increase the plant resistance against drought conditions and promotes the growth of plants by solubilization and uptake of the phosphates and micro-nutrients [7]. *Trichoderma* is successfully used against various plant pathogenic fungi of genera, viz. *Fusarium* spp*., Phytophthora* sp*., Sclerotium* spp. *Sclerotinia* spp. By production of ethylene, hypersensitive responses and defence related reactions in plants as known as inducing resistance.

Plants possess constitutive and inductive defense mechanisms against pathogen attack. Plans immunization process of activating natural defense system induced by biotic or abiotic factors. Salicylic acid is known to activate plant defense responses and function as a signal molecule within the plants. SAR is characterized by the accumulation of salicylic acid and pathogenesis-related proteins. The immunization process seems to follow a salicylic acid (SA)-dependent pathway. Once immunized the plant its activity until flowering. Immunization is a broad spectrum, effective against different pathogens.

3. Mechanisms of *Trichoderma*

Trichoderma can reduce the diseases of crops by the mechanism of one or more as given follow.

3.1. Competition

Trichoderma reduces the disease development in the rhizosphere through competition. The competition is an indirect interface between bio-agents and pathogens [26]. The pathogens are competition for nutrients such as carbon and nitrogen, space and hyperparasitism [2, 27]. Iron is an essential factor for the growth in soil; *Trichoderma* strains produce highly efficient siderophores that stop ~~the~~ growth of pathogen [4]. Siderophore is a chelates of the Fe ions that form Siderophore-Fe-complex and make unavailable to the pathogen [28]. *Trichoderma* strains can grow rapidly in the soil due to high resistance to toxic compounds and pesticides [29].

3.2. Mycoparasitism

In mycoparasitism bio-agents act through chemotrophic response recognition of the interaction of hyphae, coiling and secretion of lytic enzymes [30]. *Trichoderma* is common mycoparasitic fungi that colonize in the rhizosphere and attacks phytopathogenic fungi [31]. *Trichoderma* produces lytic enzymes *viz*., chitinases, glucanases and proteases that hydrolyze the cell wall of pathogens [32, 33]. Major constituents of many fungal cells are made up of chitin and glucan [34]. The cell wall of *Pythium* species is composed of cellulose while chitin is the main component of *Rhizoctonia*

solani [3, 35, 36]. Cell wall degrading enzymes released due to chemotrophic response from *Trichoderma* such as β-1, 3 glucanase, proteases, lipases and chitinases [37]. The initial recognition factor is lectins their after release cell wall-degrading enzymes β-1,3-glucanases, chitinases, proteinases, and lipases in the penetration [38]. Through the proteases enzyme, *T. harzianum* manage *Botrytis cinerea* [39]. Mycoparasitic activities showed by *Trichoderma harzianum* against *Rhizoctonia solsni* [40] and involve cell wall degrading enzymes chitinase and β-1, 3 glucanases [41].

3.3. Antibiosis

Antibiotics are a low molecular weight secondary metabolite, which is harmful at a low concentration to the microorganisms, produced by bio-agents in soil [42-44]. Mode of action of antibiosis as the secondary metabolites *viz.,* gliotoxin, viridin, gliovirin, viridol, koninginins, pyrones and peptaibols produced, that harmful to the growth of pathogens [45]. *Trichoderma virens* produce gliovirin which is effective against *P. ultimum,* and gliotoxin against *Rhizoctonia solan* [46].

3.4. Induce Defense and Growth of Plants

Plant roots are recognized by fungal-derived molecules that change locally and systemically in gene expression due to increasing salicylic acid, jasmonic acid, and phytoalexin levels in plants. *Trichoderma* spp. can promote growth and defense in plants. The application of *Trichoderma* in the field can promote induces resistance in plants against the diseases and give long-term protection [47]. Induced resistance in plants occurs by a wide range of biotic and abiotic agents against pathogens infection [48, 49]. Two main types of induced resistance occur in plants *viz*., systemic acquired resistance (SAR) and induced systemic resistance (ISR). Systemic acquired resistance is induced by a different variety of agents such as necrotizing pathogens and certain chemicals (acibenzolar-S-methyl, ASM), it's mediated by a salicylic acid (SA)-dependent [50]. Induced systemic resistance is a result of colonization by certain strains of plant growth-promoting rhizobacteria (PGPR) in plant roots and mediated by a jasmonate (JA) and ethylene (ET) pathway [50]. *Trichoderma* colonized roots and elicit ISR, come out defence response in subsequent pathogen infection [51, 52]. *Trichoderma harzianum* T39 induced resistance against downy mildew in grapevine [53]. Systemic Acquired Resistance is triggered by plant pathogens, and Induced Systemic Resistance is triggered by root-colonizing microbes, such as *Pseudomonas fluorescens*, *Paenibacillus polymyxa*, *Trichoderma* spp. [54-62]. SAR and ISR can differentiate based on elicitor and signaling pathways. Systemic acquired resistance is characterized by increased levels of the salicylic acid hormone. Induced systemic resistance is mediated by JA and ET and functions without PR gene activation [63-66]. Induce resistance is a indirect mechanism that triggers defence cascades inside the plants and leads to suppression of disease development. Induced defense involves the production of reactive oxygen species, phytoalexins, phenolic compounds, pathogenesis-related proteins and physical barriers [67]. *Trichoderma* can protect plants against aerial pathogen infections, through the induction of resistance via a hypersensitive response (HR), systemic acquired resistance (SAR) and induced systemic resistance (ISR) in plants [68]. *Trichoderma* bio-agent increase root development, shoot length, leaf area and crop yield *via* colonization in plant roots, the proliferation of secondary roots and solubilizing of several nutrients as P and Fe to plants [69]. They produce gluconic and citric acids that decrease the soil pH and enhance the solubilization of phosphates, micronutrients, and mineral components *viz.,* iron, magnesium, and manganese [25, 27, 70].

4. Application of *Trichoderma*

Standard air-dried mats mixed with the carrier contain 10^8-10^9 propagules per gram prepared formulation of *Trichoderma spp.* [7]. Treated seeds by *Trichoderma,* boost up seed germination, shoot enlarge, root length, solubilizing of various insoluble forms of phosphates and improved nitrogen-fixing. Formulations of *Trichoderma* spp. in the commercial form are available for controlling plant diseases [71]. It's available in the name of Trieco, Tricho-X, Ecoderma, Trichogourd, Sanjibani and Bioderma etc.

4.1. Seed Treatment

Seeds treatment with dry powder of *Trichoderma* available in commercial form, use just before sowing at 3 to 10 g/kg depending on seed size [72]. Under the biotic and abiotic stresses condition, treated seeds with *Trichoderma*, seeds germinate faster and uniformly in comparison to untreated seeds. *Trichoderma* treated seeds are sown in soil and colonized in the rhizosphere [73]. Treatment of the seeds just before sowing is an effective method for the management of pathogenic fungi such as *Rhizoctonia, Sclerotinia,* and *Macrophomina* species. *Trichoderma viride* developed talc-based formulations for seed treatment of crops [74]. *Trichoderma harzianum, Trichoderma virens* and *Trichoderma viride* are available in commercial formulations for seed protectants and use against *Pythium* spp. and *Rhizoctonia solani* [75].

4.2. Soil Treatment

Trichoderma can apply in the nursery and the field as a drench, as well as in granular form. Bio- agents apply in the soil for controlling soil-borne fungal pathogens [76]. *Trichoderma* powder applies for soil treatment with 5 kg/ hectors and mixed after turning with sun hemp/ dhaincha. The formulations of *Trichoderma* 1 kg use in 100 kg of farmyard manure and cover for 7 days with polythene sprinkle the heap with water occasionally, turn every 3-4 days interval and then mixture broadcast in the field. Nursery beds can drench at 5 kg *Trichoderma* formulation per liter of water before sowing [77].

4.3. Seedling Root Dip and Cutting

Plant cuttings and seedling roots dip is aiming to protect from pathogen infection. Root dip reduces the disease severity and enhances seedling growth in rice, tomato, brinjal, chilli and capsicum [78]. Cuttings and seedlings dip is required for 10 minutes before transplanting in nursery beds.

4.4. Aerial Spraying

The application of *Trichoderma* dosages have to be standardized based on the crop. Talc-based formulations of *Trichoderma harzianum* and *Trichoderma virens* use for foliar sprays against sheath blight of rice reduce incidence [79, 80].

5. Management of Crops Diseases

The bio-agent *Trichoderma* is compatible with organic manure, biofertilizers *viz., Rhizobium, Azospirillum, Bacillus Subtilis* and *Phosphobacteria* and also apply with metalaxyl and thiram. *Trchoderma spp* is effective against foliar diseases and soil borne plant pathogens [81]. *Trchoderma* widely used against various crops diseases and effective against *Sclerotium rolfsii, Sclerotinia* sp., *Rhizoctonia solani, Pythium* sp*., Phytopthara sp., Fusarium* sp., *Botrytis cinerea*, and *Macrophomina phaseoli.* Seed coating, furrow application and root dip of seedlings generally use for successfully diseases management. The common soil borne plant pathogens are *Pythium,* and *Phytophthora, Rhizoctonia, Fusarium* and *Sclerotium*, spp. causing diseases in several crops and effectively manage through *Trichoderma* spp. [82]. *Trichoderma* spp. has potential in controlling of wilt disease and damping-off diseases as by *Fusarium* sp. and *Rhizoctonia solani* [83]. Diseases such as foot rots, root rots, damping off, collar rots and *Fusarium* wilts successfully manage through *Trichoderma viride, Trichoderma harzianum* and *Trichoderma virens.* Trichoderma spp. has qualities that improved seed germination, plant growth development, nutrients uptake, nitrogen-use efficiency in plants and alter morphological and physiological features in different crops [84]. *Trichoderma* enhances photosynthesis activity followed with improved nutrition uptake in agricultural and horticultural crops [85]. *Trchoderma* showed positive effects on seeds germination, root length in rice and potato [86]. *Trchoderma* has potential to manage different fungal and nematode diseases and inducing defense ability in host plants [87].

6. Conclusion

Trichoderma is a beneficial micro-organism which influences soil health and crop performance. It's improved the growth of plants, length of root, plant height, and fresh and dry weight of plants. Through different mechanisms like competition, antibiosis, mycoparasitism, hyphal interactions, and enzyme secretion capable to reduces the growth of pathogens. Secreted enzymes can degrade the cell wall; and release toxic substances that can inhibit the growth of the fungal pathogens. Induce resistance occurs in plants by *Trichoderma* give the long term protection against plants diseases. *Trichoderma* can be applied to most food crops, there are no harmful effects on the environment and non-target organisms. *Trichoderma* has an important role in the bioremediation of soil that is contaminated by herbicides and pesticides as its ability to degrade. In sustainable agriculture practices, *Trichoderma* should promote crops diseases management for reducing harmful chemicals in agriculture.

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