# Implementation of *Trichoderma* spp. for Conservation of Soil Health

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**Abstract**

Applications of extensive use of fungicides for the protection of crops from diseases have serious consequences on the environment and consumers. Disease suppression, through biocontrol agents (BCAs), is outcome interaction among the plants, pathogens and the microbial community. Soil microbes are capable of influencing the productivity, composition and diversity of plant communities directly or indirectly. *Trichoderma* spp. have potential to keep safe plants from pathogen populations under distinct soil conditions. *Trichoderma* spp. produce biologically active compounds, antibiotics, hydrolytic enzymes including cell wall-degrading enzymes and secondary metabolites which act against pathogen and promote growth of plants. It also releases metabolites helping resistance against biotic stress. BCAs *Trichoderma* spp. have been studied broadly and commercially marketed as biofertilizers, biopesticides and soil amendments. In the rhizosphere region, *Trichoderma* spp. act against soilborne pathogens and have potential to conserve soil health by replacing harmful chemicals in the near future.

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## 17.1 Introduction

Applications of fungicides not only put a burden on growers but also exert harmful impact on ecosystem. Soil microbes are capable of influencing the productivity, composition and diversity of plant communities both directly and indirectly (Barea et al. 2002; Fitzsimons and Miller 2010; Lau and Lennon 2011; van der Heijden et al. 2006, 2008). A significant reduction of chemical synthetic fertilisers in agriculture is highly desirable. Biocontrol agents (BCAs) like *Trichoderma* spp. are the promising means that can replenish nutrient demands of the plants through several ways. For management of plant diseases, integrated approach of biocontrol agents with reduced doses of chemicals has been suggested to manage plant pathogens which reduced bad impact of chemicals on the ecosystem (Chet and Inbar 1994; Harman and Kubicek 1998). Dubey et al. (2007) reported integration of *Trichoderma harzianum* and carboxin enhanced seed germination grain yield and reduce wilt incidence of chickpea. *Trichoderma* spp. exhibit various biocontrol activities through mechanism such as mycoparasitism, competition and production of growth enhancer molecules which promote plant development and growth (Chadha et al. 2014). *Trichoderma* spp. are very much successful against soilborne pathogen and enhance the activity of normal plant developing process.

## 17.2 Soil Health

Promotion of soil microbial diversity maximise the coadaptation between plants and microbes. Small changes in the environment resulting from environmental stress or natural perturbations may be monitored through soils which are used as indicator (Sharma et al. 2010). Richness of species within the soil microbiome help in producing high functional inclusion allowing it to quickly recover through stress (Nannipieri et al. 2003; Yin et al. 2000).The microbial diversity of soil also endowed with protection against soilborne pathogens (Brussaard et al. 2007; Garbeva et al. 2004; Mendes et al. 2011; Nannipieri et al. 2003). The capability of the soil microbiome also plays an important role in antagonism against soilborne pathogens and increases plant productivity (Janvier et al. 2007). More than hundred species of fungi have been reported which are antagonist to plant pathogens they help in trap and prey on nematodes (Jatala 1986) as well as hyperparasites other fungi (Adams 1990). *Trichoderma* spp. secrete lytic enzymes which act against cell wall of fungal pathogens (Sivan and Chet 1989). Mendes et al. (2011) reported that diversity of soil microbiome as a whole involved different taxa or groups of microbes which convey the disease suppressive proficiency of the soil.

## 17.3 *Trichoderma*–Plant Interaction

The potential fungi *Trichoderma* is associated with plants to mitigate biotic and abiotic stresses, with matter of organic composition in the context of receptivity of the soil (Simon and Sivasithamparam 1989; Wakelin et al. 1999). Composts depict an optimal substrate for BCAs, for establishment into the environment of soil (Hoitink et al. 2006; Leandro et al. 2007). Krause et al. (2001) exhibited that inoculation of *T. hamatum* in pot mix with organic matter, supported high populations of BCAs, significantly diminished the severity of *Rhizoctonia* spp. The activity of *Trichoderma* is best in high organic matter which promotes plant growth and development.

## 17.4 *Trichoderma* Against Soilborne Pathogens

Pathogens associated with soil have a wide host range which persists for longer period as resting-resistant structures. Soilborne pathogens are controlled by chemicals, but there are also adverse effects on environment. *Trichoderma* spp. are used as fungal bioagents which are effective against soilborne pathogens (Chet and Baker 1981; Papavizas 1985; Chet 1987; Kumar et al. 1996). Roberts et al. (2005) reported that *Rhizoctonia solani*, *Pythium ultimum*, *and Meloidogyne incognita* are soilborne pathogens that cause severe economic loss. Isolates of *Trichoderma virens* are found to be most effective against *Rhizoctonia solani* causing damping off. It also improved the plant health of cucumber by suppressing *M. incognita* and *P. ultimum.* They also produce antifungal phenolic compounds which inhibit plant pathogen (Amin et al. 2010). The various mechanisms involve antagonism either through mycoparasitism, competition or antibiosis.

### 17.4.1 Mycoparasitism

Mycoparasitism is the greatest and direct form of hostility or antagonism in ecosystem (Pal and McSpadden Gardener 2006). It is one of the main mechanisms against the target organism by the action of coiling and dissolution of target pathogens cell wall through enzymatic activity (Tiwari 1996; Sharma 1996). *Trichoderma* release lytic enzymes like β-1, 3-glucanase, chitinase and proteases which act against plant pathogens (Haran et al. 1996). Lewis and Papavizas (1987) reported that *Trichoderma* spp. with alginate pellets stored for 6 weeks at temperature of 25 °C in the greenhouse were found effective against *Rhizoctonia solani* causing damping off.

### 17.4.2 Competition

Interactions between pathogens and bioagents compete for the space and nutrients. Siderophore chelate Fe(II) ions and the membrane-bound protein receptors specifically recognise and take up the siderophore-Fe complex (Mukhopadhyay and Mukherjee 1998). It makes iron unavailable to the pathogens, which produces less siderophores with lower binding power and causes less pathogenic infection. The substances act as stimulant to overcome their dormancy and exert competition and help in reducing their disease-causing ability. BCAs are more efficient in the nutrient utilisation and compete with the pathogens (Nelson 1990).

### 17.4.3 Antibiosis

Antibiosis involves antimicrobial compound to suppress fungal pathogens by disturbing their metabolic activity and stimulation of plant defence system (Corley et al. 1994; Horvath et al. 1995). Dubey et al. (2007) conducted dual culture experiment of *Trichoderma* spp. against *Fusarium oxysporum* f. sp. *ciceris* and found production of volatile and non-volatile compound-inhibited pathogen causing Fusarium wilt of chickpea.

## 17.5 Mass Production

For commercial development of biocontrol agents (BCAs), the products should be stable, potent under field conditions and above all should be economically viable (Fravel et al. 1999). Different types of grains are considered as best source of nutritive media for growing different BCAs; commonly used grains are bajra (*Pennisetum typhoides*) and jowar (*Sorghum bicolor L*). For delivery of *T. harzianum* preparations, medium of wheat bran and peat (1:1, v/v) is extensively used (Sivan et al. 1984). The pH should remain constant and low (5.5) during entire growth period, which prevent from contamination of bacterial agents. The shelf life of BCAs decreases after 1–2 years as well as number of colony-forming units (CFUs) also reduced as the time increases (Chet 1987; Elad and Chet 1995; Sivan and Chet 1992). Formulation of *Trichoderma* is prepared by the amalgamation of oils, water-soluble adjutants, stickers and different emulsions help to enhance their performance. One of the most important reasons for the limited commercialisation is the high cost of substrate, low biomass productivity and high cost of production (Rhodes 1996). The Table 17.1 shows the *Trichoderma* spp. and their application against various soilborne pathogens.

**Table 17.1** *Trichoderma* spp. and their application against soilborne plant pathogens

| Host plant | BCAs (*Trichoderma* spp.) | Causative agent | References |
|---|---|---|---|
| *Brassica oleracea* (cauliflower) | *T. viride*, *T. harzianum* | *R. solani*, *P. aphanidermatum* | Ahuja et al. (2012) and Sharma and Dureja (2004) |
| *Vigna mungo* (black gram) | *T. viride*, *T. harzianum* | *Macrophomina phaseolina*, *Alternaria alternata* | Mishra et al. (2011) and Dubey and Patel (2001) |
| *Agaricus bisporus* (mushroom) | *Trichoderma viride* | *Rhizopus stolonifer*, *Fusarium oxysporum* | Rawal et al. (2013) |
| Citrus | *T. viride*, *T. harzianum* | *Fusarium solani* | Kalita et al. (1996) and Singh et al. (2000) |
| *Brassica oleracea* (cauliflower) | *T. viride*, *T. harzianum* | *R. solani*, *P. aphanidermatum* | Ahuja et al. (2012), Sharma and Dureja (2004), and Sharma and Sain (2005) |
| *Capsicum annuum* L. (chilli) | *Trichoderma viride*, *Trichoderma harzianum* | *S. rolfsii*, *Fusarium oxysporum*, *Pythium* spp. | Kapoor (2008), Rini and Sulochana (2006) and Vasanthakumari and Shivanna (2013) |
| *Cicer arietinum* (chickpea) | *Trichoderma harzianum*, *Trichoderma viride* | *Fusarium oxysporum*, *Rhizoctonia solani*, *Macrophomina phaseolina* | Mukherjee et al. (1997), Pandey et al. (2003) and Poddar et al. (2004) |
| *Solanum melongena* L. (brinjal) | *Trichoderma viride*, *Trichoderma harzianum* | *Fusarium solani*, *Fusarium oxysporum* | Jadon (2009) and Balaji and Ahir (2011) |
| *Gossypium hirsutum* (cotton) | *T. viride*, *T. harzianum* | *R. solani*, *S. rolfsii*, *P. aphanidermatum* | Gaur et al. (2005) |

## 17.6 Role of *Trichoderma* as Bioremediator

The fungi most potent used widely for bioremediation is *Trichoderma* spp. The BCAs help in promoting growth of the plants, as well as improvement of soil fertility, diseases suppression and composting (Contreras-Cornejo et al. 2009; Lorito et al. 2010). *Trichoderma* spp. are the producer of organic acids, which help in reducing soil pH and promoting dissolution of macro- and micronutrients such as iron, manganese and magnesium, which are necessary for plant metabolism. *Trichoderma* are capable to degrade chemical pesticides, chlordane, lindane and DDT which resides in soil and make contaminant-free sites (Ezzi and Lynch 2005). Table 17.2 shows the bioremediation of various contaminants by different *Trichoderma* spp.

**Table 17.2** Mycoremediation of soil contaminants using various *Trichoderma* spp.

| S. No. | Soil pollutants | *Trichoderma* spp. | References |
|---|---|---|---|
| 01. | Cadmium, lead, manganese, nickel and zinc | *Trichoderma harzianum* | Adams et al. (2007) |
| 02. | Poly resistance of pesticides | Spp. of *Trichoderma* | Hatvani et al. (2006) |
| 03. | Water and soil contaminants | Spp. of *Trichoderma* | Harman et al. (2004) |
| 04. | Various types of heavy metals from mud sludge | *Trichoderma atroviride* | Errasquin and Vazquez (2003) |
| 05. | Phytoextraction in cadmium- and nickel-polluted soils | *Trichoderma atroviride* | Cao et al. (2008) |
| 06. | Heavy metals | *Trichoderma* | Hajieghrari (2010) |
| 07. | Agrochemicals pollutants DDT, dieldrin, pentachlorophenol endosulfan and pentachloronitrobenzene | *Trichoderma harzianum* | Katayama and Matsumura (1993) |

## 17.7 *Trichoderma*-Induced Plant Health

*Trichoderma* genes enhance plant resistance by expressing broad range of stress, and tolerance in the plant genome efforts is in progress. Lorito et al. (1998) demonstrated that genes of *Trichoderma* spp. expressed functional enzymes to control plant diseases. Gene endochitinase chit42 of *Trichoderma harzianum* were obtained from different plant tissues, which show no effect on plant growth and development but work against plant pathogen. In transgenic cotton plants, endochitinase gene Tv-ech1 of *Trichoderma virens* showed significant resistance against *A. alternata* and *R. solani* (Emani et al. 2003; Kumar et al. 2009).

## 17.8 Conclusion

The success of genus *Trichoderma* as bioagents is based upon the complicated interactions between advantageous microbes which establish with plants and pathogens in the soil ecosystem. Fungicides control pathogens effectively, but the accumulation and persistence of chemicals pollute soil which effect human health. For the protection of plants and their crop yield, *Trichoderma* spp. are the best and safer option. Advancement of modern techniques like proteomics and metabolomics could provide best knowledge about the complex tripartite interaction of *Trichoderma* with environment and plant microbial community (Vinale et al. 2008). Further experiments should be conducted to understand the mechanisms of *Trichoderma* secondary metabolites and their possible synergisms with other compounds used in agriculture. For marketability enhancement of *Trichoderma* spp. as BCAs, commercial production should be improved.

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