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Trichoderma: A Beneficial Organism for Agriculture

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A B S T R A C T

Trichoderma spp. are the most commonly used and widely applied biocontrol agents which is known for its antagonistic activities against plant pathogens especially soil borne pathogens such as *Fusarium* spp. (Fusarium wilt), *Rhizoctonia*, *Pythium* (Damping off), *Sclerotium rolfsii* (Sclerotinia rot), etc. Trichoderma exhibit diverse array of activities viz. plant growth promotion, biofertilizer, bioagents through the production of different biocontrol mechanisms (enzymes) such as chitinase, protease, glucanase, etc. Their mode of action is either by parasitizing the plant pathogens, secreting antibiotics or by competing for space and nutrients. Nutrient uptake is also enhanced as it regulates the root architecture promoting better root growth. Recently studies have found that it can also be utilized for bioremediation which will play a pivotal role in rejuvenating the environment from toxic substances. Heavy metal contaminants like Ni, Cd, Zn, Pb, As has been tolerated and accumulated by Trichoderma sp. Decomposition rate was fastened when Trichoderma was inoculated in agricultural waste substrate. It can detoxify toxic pesticides and fungicides which will be of great help in solving the environment pollutants besides increasing the soil fertility. Its role as biocontrol and as bioremediation can be of great advantage to the agriculture sector in solving disease problems and providing safe environment.

Introduction

In the field of biocontrol of plant pathogens especially soil borne plant pathogens, Trichoderma is widely used for its diverse functions. *Trichoderma* species belongs to the division Ascomycota, subdivision Pezizomycotina, class Sordariomycetes, subclass Hypocreomycetidae, order Hypocreales and family Hypocreaceae (Kamala *et al.*, (2015). Rifai introduced the concept of "species aggregate" and categorized *Trichoderma* strains into nine aggregates based on morphological features (Rifai, 1969). Chaverri *et al.*, (2015) have reidentified the ubiquitous *Trichoderma harzianum* into 14 new species with various characteristics. Trichoderma's role in biocontrol is widely known and proved effective in controlling many plant diseases. The biocontrol potential of *Trichoderma* spp. is due to their complex interaction with plant pathogens either by parasitizing them, secreting antibiotics or by

competing for space and nutrients. During mycoparasitic interactions, production of hydrolytic enzymes such as glucanase, chitinase and protease were observed which were found to aid in disease control mechanisms. The use of *Trichoderma* spp. relate to plant disease control, plant growth, decomposition process and bioremediation. The paper reviews the utilization of Trichoderma as biocontrol agents and as bioremediation.

Trichoderma as a bioagent

Almost 20 species of the genus *Trichoderma* act as bioagents against many soil-borne as well as foliar plant pathogens. *T. harzianum*, *T. koningii*, *T. viride*, *T. atroviride*, *T. pseudokoningii*, *T. longibrachiatum*, *T. hamatum*, *T. polysporum* and *T. reesei* are the most important species, which act as potential antagonists (Monaco *et al.,* 1991). Antagonism of *Trichoderma* against different pathogens has been reported for several times like *Sclerotium rolsfii* (Mukherjee and Tripathi, 2000), *Fusarium ciceris*, *Macrophomina phaseolina*, *Rhizoctonia solani* (Mukhopadhyay and Pan 2012a) and plant parasitic nematodes (Spiegel and Chet, 1998). Mukherjee and Raghu (1997) observed that *Trichoderma* species and *Gliocladium virens* were highly effective in suppressing *S. rolsfii* on ginger rhizomes and on several vegetables in storage. Li *et al.,* (2018) showed that 4 species of *Trichoderma* restricted *Fusarium oxysporum* growth by producing volatile compounds.

Trichoderma spp. significantly suppress the growth of plant pathogenic microorganisms and regulate the rate of plant growth. Recent works have shown that common plant disease such as root rot disease, damping off, wilt, fruit rot and other plant diseases can be controlled by *Trichoderma* spp. (Begum *et al.,* 2010; El Komy *et al.,* 2015; Howell, 2002; Mbarga *et al.,* 2012). The secondary metabolites secreted by *Trichoderma* spp. have proven its role in suppressing the growth of pathogenic microorganisms and stimulating the plant growth (Contreras-Cornejo *et al.,* 2015a, Contreras-Cornejo *et al.,* 2015b; Kubicek *et al.,* 2001; Kullnig *et al.,* 2000). Besides, the interaction between plant and *Trichoderma* spp. successfully regulate root architecture, increase the length of lateral and primary root that result in the effectiveness of nutrient uptake by the plant (Cai *et al.,* 2013; Naseby *et al.,* 2000; Yedidia *et al.,* 2001). Biocontrol agent like *Trichoderma* has been an integral part of Integrated Pest Management (IPM) to control the pests and diseases in an environmentally friendly manner (Monte, 2001).

Bioremediation

The discovery of *Trichoderma* spp. as natural decomposition agent and biological agent of bioremediation has been reported by several studies. The rate of decomposition process increases when there is the inoculation of *Trichoderma* spp. in an agricultural waste substrate such as empty fruit bunches (EFB), palm oil mill effluent (POME) and crop residues (Amira *et al.,* 2011; Sharma *et al.,* 2012). Recent works have shown that the ability of *Trichoderma* spp. to detoxify pesticides and herbicide have been revealed in several findings (Vázquez *et al.,* 2015; Zafra *et al.,* 2015). Both of these potentials give significant advantages to the agriculture industry to overcome pollution-related issues.

Since the challenges in coping with issues in the agriculture industry have grown tremendously, sustainable strategies by using biological control approach are necessary. Thus, the use of *Trichoderma* sp. as a biological agent seems to be an excellent approach.

Bioremediation and phytoremediation in association with microbes are innovative technologies having the potential to alleviate various soil pollution problems.

Table.1 Bioremediation offered by Trichoderma species

S.No.	Agro-chemical category	Microorganisms	References
1	Organophosphate pesticide dichlorvos	*T. atroviridae*	Tang *et al*., 2020
2	PGPR in metal-contaminated soil	*T. harzianum*	Adams *et al*., 2007
3	Pesticide-poly resistance Cyanide	*Trichoderma* spp	Kredics *et al*., 2004
4	Soil and water pollutants	*Trichoderma* spp	Hatvani *et al*., 2006
5	Heavy metals, organometallic compounds, agrochemicals, tannery effluents, and harmful chemicals like cyanide	*Trichoderma* spp.	Harman *et al*., 2004
6	Agrochemicals viz. DDT, dieldrin, endosulfan, Penta-chloro-nitro-benzene, and Penta-chloro-phenol	*T. harzianum*	Katayama and Matsumura, 1993
7	Chlorpyrifos and photodieldrin (pesticides)	*T. harzianum*	Tabet and Lichtenstein, 1976

The genus Trichoderma is genetically very diverse with a variety of capabilities among various strains with agricultural and industrial significance. (Tripathy *et al.,* 2013). Trichoderma alleviates contaminants by acting upon chemicals, metal contaminants by the activity of various enzymes and improves the physical and chemical properties of soil (López and Vázquez, 2003). Heavy metal contaminants like Ni, Cd, Zn, Pb, As has been tolerated and accumulated by Trichoderma sp. (López and Vázquez, 2003), Tripathi *et al.,* 2013). Agrochemicals application in intensive cultivation has accumulated the contaminants and degrading the soil health and crop performance. Trichoderma inoculation in soil has reported to degrade the chemical pollutants and make nutrients available to plants from those agrochemicals too (López and Vázquez, 2003). Some of the agrochemicals bioremediation evidence has been presented in Table 1

Trichoderma is one of the beneficial micro-organisms in the agro-ecosystem which influences soil health and crop performance. Its antagonistic feature with plant pathogenic micro-organisms makes it more reliable for use in the agriculture field. However, its use is not limited to anti-pathogenic activity but also acts as biofertilizer, plant growth promoter, bioremediation, and increase in crop yield both biological and economic yield. Farmers in India are less aware of the benefits Trichoderma brings in the field of agriculture. More awareness programme needs to be conducted to prove the efficacy of Trichoderma in optimizing yield and disease control. Use of *Trichoderma* should be promoted as it promises for sustainable agriculture so that the use of harmful chemicals is minimised in agriculture

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