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REVIEW ARTICLE

TRICHODERMA: A VALUABLE MULTIPURPOSE FUNGUS FOR SUSTAINABLE AGRICULTURE

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ABSTRACT

A most valuable fungus that has multiple benefits in the agriculture production system. Around the Globe, Framers and scientists have taken the benefit of knowledge on trichoderma use. It is also called as multipurpose fungus because of its use as bio fertilizer as well as biofungicide (Bio agent). Trichoderma is being able to produce volatile compound and ability to solubilize phosphate making them available to plants, it's used as biofertilizer. As a bioagent it control various pathogens such as Rhizoctonia, Phytophthora, Sclerotinia spp. Presently a large number of Trichoderma based formulations/ Products are available in the global market which are dominated by Trichoderma harzianum & Trichoderma viridae. Its application in developed countries is increasing rapidly replacing the chemical products, while in developing countries still it is lagging behind because of awareness among the peoples. This article is also with purpose to disseminate the awareness among the peoples about its beneficial aspects in crop production process and its contribution in the environment. The main Ambition of this review paper is also to enlight the importance of trichoderma as a biofertilizer and bio agents.

KEYWORDS

BCA (biological control agents), *Trichoderma*, Bio fertilizer, Bio agents, Phytopathogen

1. INTRODUCTION

Huge agriculturally important crops face losses due to the disease caused by fungus and bacteria. These diseases are more preferably controlled by the use of chemical method and using such chemicals cause impact on human health and environment and develop resistance in the pathogen which later becomes difficult to control. Today's approach is to control these diseases by using biological control agents (BCA). BCA are the organisms that suppress the pathogen or it's activity is referred to as BCA. Adopting biological control is potent mean of minimizing the damage caused by pathogen and environmental safety. The species of *Trichoderma* is globally accepted for their bio control ability in addition to plant growth promotion and development (Vinale et al., 2014). Trichoderma (BCA) is a genus of fungi that are present sufficiently in the soils. They are fast growing, highly adoptable fungi that form symbiotic relationships with plant root making them suitable to use to control phytopathogens. The bio control potential in *Trichoderma* species is only due to their complex interaction with phyto pathogens either by parasitizing them, secreting antibiotics or by competing for space and nutrients availability. Important Species of Trichoderma are; *Trichoderma viridae, Trichoderma harzianum, Trichoderma virens, Trichoderma asperellum etc.* are being used as bio pesticide to control plant disease.

2. CHARACTERISTICS OF TRICHODERMA

Trichoderma spp. are mostly found wherever decaying plant materials are available and are mainly of cellulosic materials. *Trichoderma* spp. are mainly characterized by branched conidiophore bearing bright green conidia as in Figure 1. According to a study, the light green color of conidia of *T. harzianum* are globose to subglobose (Shah et al., 2012).

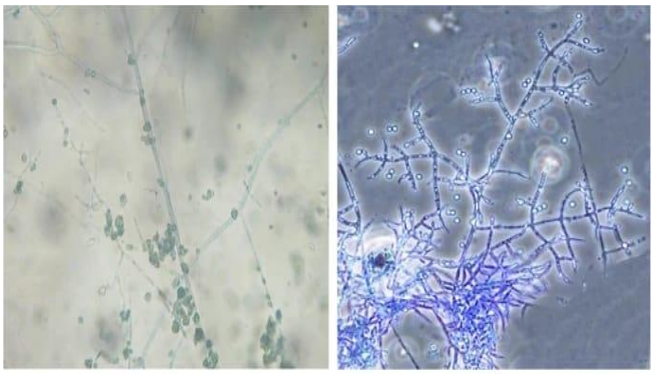

Figure 1: *(a) Trichoderma harzianum; (b) Trichoderma viride* (Viewed in University de Bretagne Occidentale website)

3. TRICHODERMA AS BIOFERTILIZER

Using *Trichoderma spp* as bio fertilizer is very excellent amendments to boost crop production alternative to the chemical fertilizers. Trichoderma has inborn potential to enhance/ stimulate the plant growth in different ways, so it is used as bio fertilizer in many agriculturally important crops. It minimizes the employment of traditional chemical-based fertilizers and also improve the uptake of micronutrients to plants, solubilization of (P) phosphate in soil and make available to plants.

Trichoderma as a biofertilizer was reported high to be utilized in vegetable production process and was found most effective in tomato. However, a

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positive response was also recorded from other crops like as cauliflower, onion, peas, tobacco, Bengal gram, Potato, soya bean and sunflower etc. Many attributes are there that qualify it to be used as an alternative to enhance fertilization and agriculture sustainability. Among these some are: -

3.1 Macro and Micronutrient Uptake

The presence of *Trichoderma* within the rhizosphere accelerates the nutrient uptake and availability. This is the most important attribute which indicate that the presence of Trichoderma in the root zone helps to convert the unavailable form of nutrients to the available form and hence improve the nutrient uptake. It is reported that in Acidic soil the applied chemical fertilizers won't be available in sufficient quantity to the crop. This is because of conversion into unavailable form and forming complex (Aluminum complexes) that can be even more toxic to the plant. The additive advantage is that *Trichoderma* colonizes the rhizosphere and enable the crops to take more from the soil. It is found that sugarcane crop inoculated with *Trichoderma viridae* gained more Nitrogen, Phosphorus, Potassium and organic Carbon content.

3.2 Phosphate Solubilization

Phosphorus is the most crucial nutrient that the crop needs for its growth and development. Our soil has phosphorus content but is in unavailable form to the crops. Acidic soil restricts the availability of phosphorus by binding it and forming complexes. At this case *Trichoderma* spp. only can mediate the process by solubilizing and converting them back into available form for crop production. Phytase enzyme produced by some species of trichoderma is responsible to conversion of unavailable phosphorus into plant available form.

3.3 Production of Phytohormones and Volatile compound

Phytohormones are responsible for root and shoot development of plant. The growth promotion found to be assisted by auxin production by the fungus, which lowers down the high levels of ethylene that gets accumulated during various stresses. In rhizosphere the presence of *Trichoderma* enhances the production of Phytohormones such as Auxin, IAA and gibberellic acid which ultimately promote growth of plants. Trichoderma also enhance germination percentage and improves seedling vigor, which is an advantage for the crop.

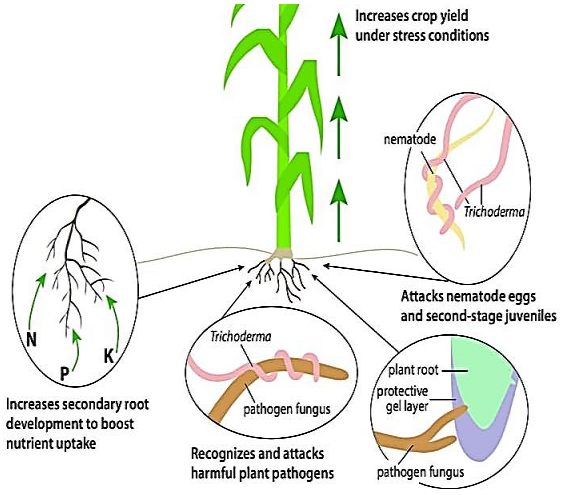
3.4 Enhance Greater Root System and Boost Up Plant Health. Also Provides More Niches for Growth of The Fungus.

Table 1: *Trichoderma* as bio fertilizer and mode of application

Bio fertilizer	Crops	Method of application	Yield
Trichoderma asperellum	Rice	Seed Inoculation	Increased by 30%
T. harzianum	Mustard and Tomato	Inoculation in Soil	50% Nitrogen and Trichoderma enriched increased yield by 108 & 203% over control
	Cucumber	Inoculation in Soil	N/A but improved fruit quality and crop growth
	Chilli	Inoculation in Soil	Increase in yield by 11 quintal/ha, than that of control (58 q/ha)
	Barley	Seed Inoculation	Increase in yield by 17%
T. viridae	Wheat	Soil and Seed Inoculation	75.8% with NPK and by 41.8% with well rotten FYM.
	Potato	Inoculation in Soil	16.25 tubers/plant than that of control which was 2.25 tubers/ plant
	Red Beet Cabbage	Seed Inoculation	Increased by 29%

4. TRICHODERMA AS BIOAGENT/FUNGICIDE

Agriculture is the crucial part of any country to feed huge populations. However, agriculturally important crops are attacked by several pathogens which in turn results serious yield reductions threatening global security. In order to control these pathogens, amplified use of synthetic chemicals occurred which have caused negative impact on environmental quality and resulted in increasing trend of many living forms which are resistant with the chemicals. Concerning these threatening issues, the search of non-chemical alternatives has been focused which result in emergence of Bio control agent as vital component of plant disease management. *Trichoderma* spp. naturally free-living fungus and cosmopolitan in distribution that are found abundantly in soil, decaying organic matter. In early 1930s, *Trichoderma* first reported as biocontrol agents for the control of root rot causing *Amrillaria mellae* in citrus.



Almost 20 species of the genus *Trichoderma* act as bio agents against Almost 20 species of the genus *Trichoderma* act as bio agents against most of soil-borne pathogen as well as foliar plant pathogens. *T. harzianum, T. koningii, T. viride, T. atroviride, T. pseudokoningii, T. longibrachiatum, T. hamatum & T. reesei* are the most preferred species, which act as potential antagonists (Monaco et al., 1991).

4.1 Mechanism of Pathogen Control/ Bio control

Trichoderma have potential to compete for the nutrient and ecological niche. Some of the major biological mechanisms that are involved independently or together in antagonistic activity against phyto pathogen are given below:

4.1 Mycoparasitism/Hyperparasitism

Mycoparasitism refer to the parasitic interaction between two fungi in which one fungus (Host) is parasitized by the mycelia of other fungus (Parasite). Mycoparasitism is the common mechanism shown by *Trichoderma* spp. After identifying the host, *Trichoderma* hyphae attach to the host hyphae by twisting and then penetrate host cell wall through secretion of cell wall degrading enzymes and take nutrients from host and use it for growing. In a study, it was reported that some strains of *T. harzianum* have capicity to parasitize on nematodes and their egg masses, where it coiled around the second stage juveniles of Nematode and then penetrated them by forming haustoria like structures and disable them (Sahebani and Hadavi, 2008).

4.2 Antibiosis

Antibiosis states to the antagonistic association between two microorganisms, in which one is adversely affected by metabolites or antibiotics released by another. It is the important attributes for deciding the saprophytic ability of the fungus. Antibiotics such as trichodermin, suzukacillin and alamethicin produced by *T. harzianum* affect morphological or physiological sequences leading to its successful penetration. *Trichoderma* can also produce a multitude of compounds that have antagonistic properties including cell wall degrading enzymes like as cellulase, xylanase, pectinase, glucanase, lipase, amylase and protease, volatile metabolites such as 6-npentyl-2H-pyran-2-one (6-PAP) etc.

4.3 Competition

The most common cause of death of microorganisms is starvation, so the competition for macro, micro-nutrients and spaces, results in the biocontrol of fungal phytopathogens. *Trichoderma* exhibits a better

potentiality of absorption and mobilization of nutrients from the limited available substrate from environment comparative to other rhizospheric microorganisms; therefore, the bio control of fungal pathogens using *Trichoderma* involves the coordination of numerous strategies, such as the competition for nutrients and space which is considered among the most important one. Thanasoulopolos found that *T koningii* as rhizosphere competent microbe, when tomato seed is treated with conidial suspension of *T. koningii* was sown, resulted in reduced damping-off pathogen (Thanasoulopolos, 2002).

Plant- Pathogen interaction leads to develop wide range of defense mechanism in plant, which can prevent plant from attack by invading pathogen. Among many, some of the bio-control strains of *Trichoderma* sp. are known to induce systemic resistance (ISR) and host plant defense against a variety of phytopathogen which is mediated by jasmonic acid (JA)/ethylene. The rhizosphere competent nature of *Trichoderma* species permit it to colonize roots, triggering the plant immune system and pre-activation of the molecular mechanisms of defense against several potent phyto pathogens and the stress challenged situations.

4.4 Bio Priming of Resistance Mechanism in Host Plant

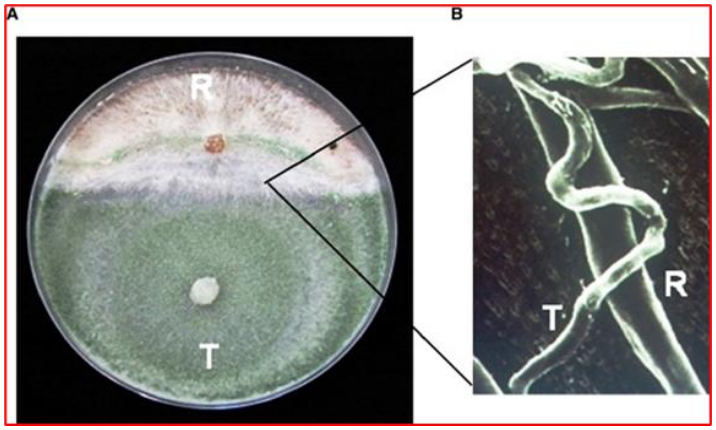


Figure 2: (A) Mycoparasitism confrontation assay; (B) Coiling of *Trichoderma* (T) hyphae around the phyto pthogen *Rhizoctonia solani* (R) (Image source-Google)

5. Trichoderma Spp. In Bioremediation

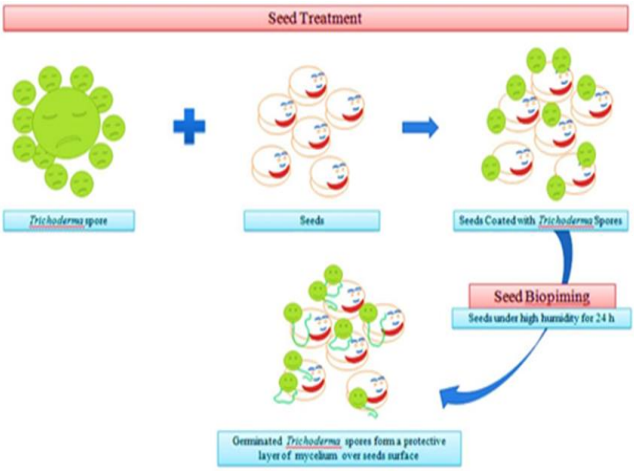
After the green revolution there occurred blind application of chemical fertilizers and pesticides that contaminated and caused soil related constraints. For the remediation scientists tried to use *Trichoderma* like microorganisms in soil and reported a surprising result that these microorganisms degraded the chemical contaminants present in the soil. Microbes in Bioremediation and phytoremediation are excellent and innovative technology that has the potential to remediate various soil related constraints. Trichoderma releases some enzymes that act upon chemicals and metal contaminants which ultimately improve the physical, chemical and biological properties of soil. Trichoderma not only degrade the chemical contaminants but also make the nutrients available to plants from those chemicals' contaminants too.

6. Delivery (Application) Method of Trichoderma Formulation

Site specific delivery of the Trichoderma is very essential to enhance the efficiency. The most common and effective methods of application of Trichoderma are mentioned below:

6.1 Seed Treatment

Most effective method to prevent the soil borne pathogen and enhance the germination of seed. The seed must be coated with the powder just before sowing and for that, the seed should be moistened by the molasses solution (Enhance The stickiness) and Trichoderma powder is to be sprayed@ 10gm per Kg of seed. Mix the powder properly and spread in shade to dry. Propagules of bio control agents germinate over the surface of seed and colonize roots of germinated seedlings and rhizosphere.



6.2 Seed Bio Priming

It is the process of treating the seed with Bioagents i.e. *Trichoderma* and then incubating it in warm and moisten condition until just prior to the emergence of the radicle. It has potent advantage over the simple/normal coating of the seed as it results in rapid and uniform emergence. Bioprimed seed will be surrounded by a layer of *Trichoderma* conidia and such seed can tolerate adverse conditions. Bioprimed seed also show higher germination percentage.

6.3 Soil Treatment

In direct broadcasting, 300g of Trichoderma powder is mix uniformly in 6 kg of FYM now broadcast in irrigated land of area 1 hectare. Another furrow application is highly effective mode of treatment in which root crops like potato, ginger, turmeric are highly benefited. Here, uniform mixture of 300g+6FYM is applied at the time of earthing up or after 28-30 days of planting. Trichoderma is capable of colonizing farmyard manure (FYM) and therefore the application of colonized FYM to the soil is more appropriate and is beneficial. It is the most suited method of application of *Trichoderma* particularly for the management of soil-borne diseases.

6.4 Cutting and Seedling Root Dip

Trichoderma powder of about 10grams should mix with 100g of well rotten farmyard manure per liter of water and dipping the cuttings and seedling in *Trichoderma* suspension just before transplanting. Dipping in antagonist's suspension not only inhibits the disease severity but also induce the seedling growth and development.

6.5 Nursery Treatment

Formulate a suspension by adding 250 gm in 50 liters of water then drench in nursery bed soil of area 400 sq.m. Application of FYM manures and neem cake before treatment induced the efficiency of the Trichoderma.

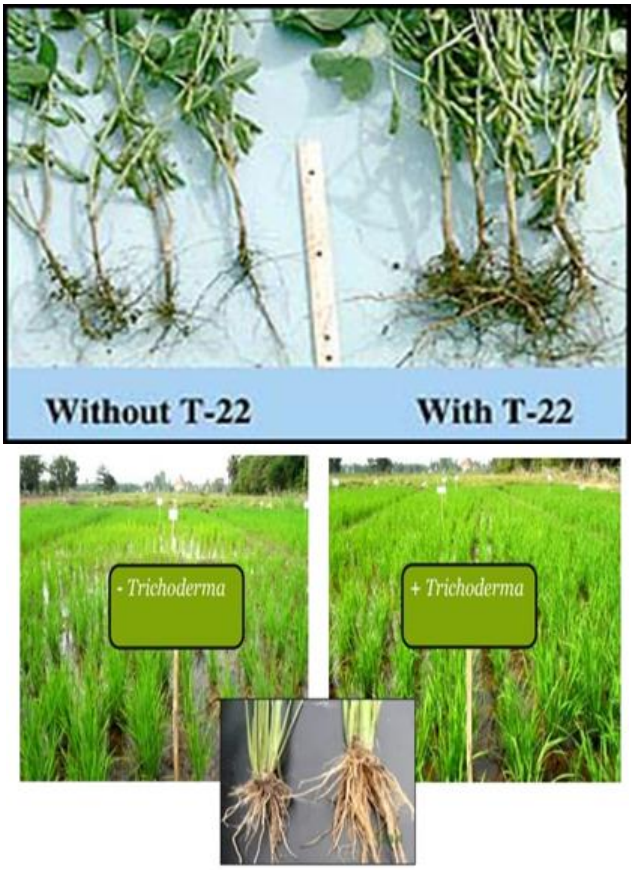


Figure 3: Comparison among *Trichoderma* applied crop and not applied crops.

7. Conclusion

Trichoderma spp are the boon for the agriculture world. In the disease prevention as well as nutrient availability, it has demonstrated best of its potential to be used as biofertilizer as well as bioagents. It has also shown its sustainability and various mechanisms of availing the crop with nutrients and disease prevention. Moreover, it has various control mechanisms for phyto pathogens, and gives it as additive advantage when compared to other plant pathogen control mechanisms. Hence this can be the best option for farmers to use for sustainable cropping, increase yields and quality of the produce to feed the global population.

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