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Application of *Trichoderma* spp. Restoration in Soil Health

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A B S T R A C T

The rampant uses of chemical pesticides by developing countries not only pollute the soil, also problem to environment and human. The current scenario is pollution of soil contaminated with heavy metals(HMs). Contamination of soil bad impact on both yields and crop qualities leads to decrement of agriculture productivity. The pathogen inhabitant in soil also responsible for contamination of soil. Soil is dwelling place of plant pathogenic fungi which cause diseases to the crops. Among the fungal biocontrol agents *Trichoderma* spp. are being used most abundantly against plant pathogens. Several species of *Trichoderma* produce volatile and non-volatile antibiotics and enzymes. They are antagonistic to phytopathogenic fungi and nematodes. *Trichoderma* spp. is free-living and abundantly present in the soil and rhizosphere region, they mycoparasites several soilborne plant pathogens. *Trichoderma* spp. helps to concentrate and absorb heavy metals (HMs), it acts as hyper accumulator. It helpsin breaking down of various toxic substances for sustain soil health. *Trichoderma* spp. have great potential against soil borne pathogens, and it may be able to replace chemical pesticides in the near future.

Introduction

Chemical pesticides are abundantly used by farmers in the developing countries, polluting soil and water leading health problem to human and animals (Forget, 1993; Igbedioh, 1991). Soil microbes are capable of both directly and indirectly influencing the

productivity, composition, and diversity of plant communities (Barea *et al.,* 2002; Fitzsimons and Miller 2010; Lau and Lennon 2011; van der Heijden *et al.,* 2006, 2008). These pesticides deteriorate the microbial community of the soil. India is the second largest manufacturer of pesticides inAsia after China and ranks twelfth globally (Mathur, 2010; Bhardwaj and Sharma, 2013). Biocontrol agents (BCAs) like *Trichoderma* spp. are the promising means that can replenish nutrient demands of the plants through various ways.

For the management of plant diseases, integrated approach of BCAs with reduced doses of chemicals have been suggested to manage plant pathogens resulting in minimal impact of the chemicals have on the environment (Chet and Inbar, 1994; Harman and Kubicek, 1998). The mechanism involvessuch as mycoparasitism, competition and production of growth enhancer molecules which promote plant growth and development.

It helps fight against soil borne pathogens. Remediation deals with the removal of pollutants from contaminated soil and support conservation of natural resources. *Trichoderma* spp. plays an important role in restoration of soil health by mycoremediation, secretion of certain enzymes help in decomposition of hazardous chemicals into nontoxiccompounds (Barry *et al.,* 1994).

Soil health

Karlen *et al.,* (1997) defined soil as the "capacity of a soil to function within ecosystem boundaries for sustainable plant-animal productivity. This leads to maintain human health habitation. Richness of species within the soil microbiome help in producing high functional inclusion allowing quickly recover during stress (Nannipieri *et al.,* 2003; Yin *et al.,* 2000). The soil microbial diversity also endow with protection against soil-borne diseases (Brussaard *et al.,* 2007; Garbeva *et al.,* 2004; Nannipieri *et al.,* 2003). The capability of the soil microbiome plays an important role in antagonism against pathogens present in soil and helping plant productivity (Janvier *et al.,* 2007).

During management practises manipulation of quality and quantity of organic inputs ramify the action of soil microbiome, and biological processes of nutrient transformation within the soil (Stockdale *et al.,* 2002). *Trichoderma* spp. secretes lytic enzymes which act against cell wall of fungal pathogens (Sivan and Chet 1989).

Mechanism

Plant diseases results interaction among various component consist of host, pathogen and environment i.e. diseases triangle. BCAs are the organism manage diseases by the interaction various components of diseases triangle. BCAs involve several types of mechanisms in achieving disease control. However, the conclusive evidences for the involvement of a particular factor in biological control are determined by the strict correlation between the appearance of factor and the biological control (Handelsman *et al.,* 1989).

Mycoparasitism

Mycoparasitism is one of the main mechanism against the target organism by coiling and dissolution of target pathogens cell wall through enzymatic activity (Tiwari 1996; Sharma 1996). *Trichoderma harzianum* exhibits excellent mycoparasitic activity against *Rhizoctonia solani* hyphae (Altomareet al.1999). Mycoparasitism having enzymatic activity which are anagonist to pathogen. Harman (2000) reported the

involvement of chitinase and β-1, 3 glucanase in the *Trichoderma* mediated as biocontrol agents. Gupta *et al.,* (1995) reported that a strain of *Trichoderma* deficient in the ability to produce endochitinase had reduced ability to control *Botrytriscineria*but shows increased ability to control *Rhizoctonia solani.*

Competition

Interaction between the pathogen and the bioagents compete for the nutrients and space to get them established in the environment while pathogens are excluded by the depletion of food base and physical occupation of site (Lorito*et al.,* 1994). BCAs compete with essential micronutrients such as iron and manganese especially in highly oxidized and aerated soils. BCAs are more efficient in the nutrient utilisation and compete with the pathogens (Nelson 1990).

The production of iron binding ligands called siderophores as in *Erwiniacaratovora.* Siderophoreschealate Fe (II) ions and the membrane bind protein receptors recognize and take up the Siderophore-Fe-complex (Mukhopadhyay and Mukherjee 1998). It makes iron unavailable to the pathogen, which produce less siderophores with lower binding power and causes less pathogenic infection. These substance acts as stimulant to overcome dormancy and exert competition and help in reducing disease causing ability.

Trichoderma against soil borne pathogen

Pathogens associated with soil having a wide host range which persists for longer period as resting resistant structures. Soil borne pathogens control by chemicals but there are also adverse effects on environment as well as affecting the beneficial soil microorganisms. *Trichoderma* spp. is used as fungal biological control agent commonly have been known effective antagonists against plant pathogenic fungi (Chet *et al.,* 1981; Papavizas 1985; Chet 1987; Kumar and Mukerji 1996**).** The inhibitory activity of *Trichoderma harzianum, T. viride* and *T. virens* against soil borne fungal pathogens has been reported (Dohroo *et al.,* 1990; Abdollahzadeh *et al.,* 2003). The mechanism involves either through antibiosis or mycoparasitism due to competition for space, nutrition between the pathogens and the antagonist. They also produce antifungal phenolic compounds which inhibit plant pathogen (Banday *et al.,* 2008).

Trichoderma as bioremediator

Trichoderma is soil borne fungi plays an important role in the bioremediation of contaminated soils and can be applied in integrated pest management and phytoremediation. They also have known to enhance plant growth and development. BCAs help in promoting growth of the plants, as well as improvement of soil fertility, disease suppression and composting (Contreras-Cornejo et al.2009).

Trichoderma spp.is a producer of organic acids such as gluconic acid, fumaric acid, and citric acid, which help in reducing soil pH, promote phosphate dissolution, dissolution of macro and micronutrients such as iron, manganese, and magnesium that necessary for plant metabolism. Moreover, it can remove and concentrate the various ions such as Pb, Cd, Cu, Zn, and Ni widely recognised as the main mechanism of uptake (Srivastava etal. 2011). *Trichoderma* apply in facilitating metal stress tolerance in plants imputed to improve root biomass and enhanced nutrient availability and efficiency (Arriagadaetal. 2009; Mastouri*et al.,* 2010).

Mycoremediation of inorganic pollutants by *Tricoderma* spp.

Contaminants like HMs from sewage sludge

which cannot be destroy easily, they live in soil for a long period of time. It makes soil unfertile and uneasy for farmer to grow crops. HMs like cadium, mercury, copper, zinc and arsenic increasingly released in the environment by the use of pesticides, fertilizers and other anthropogenic activities (Errasquin and Vazquez 2003; Tripathi *et al.*, 2007).Fungi like *Trichoderma* spp. play an important role to degrade and detoxify toxic substances. Kredics *et al.,* (2001) reported that four *Trichoderma* isolates out of 13 tested against Ni, As, and Zn possessed an effective soil colonization and showed high biodegradation potential.

Mycoremediation of organic pollutants by *Tricoderma* spp.

Organic chemicals such as Polycyclic aromatic hydrocarbons (PAHs) are potent environmental pollutants which consist of three or more fused benzene ring in linear. PAHs are sparingly soluble, hydrophobic, and strongly bound to soil particles. They damage genetic materials and change the structure of cells (Pashin and Bakhitova 1979). The techniques such as biostimulation, bioagumentation, areration and turning or combining these practices help in bioremediation. The substrate of bioremediator which act upon bio waste and contaminated soil (Alexander 1994). The responses of 25 Trichoderma spp. are reported against PAHs.

Among them *Trichoderma longibractum* proved more tolerant than other strain (Oros *et al.*, 2011). The fungus *Trichoderma* was identified as dominant in the diesel-contaminated compost, which have the potential to colonize and help in degradation ofdiesel-contaminated soil (Hajieghrari 2010). Mishra and Nautiyal (2009) demonstrated *Trichodermaressei* having potential to promote plant growth in soil with diesel as pollutant.

Mycoremediation of agrochemicals by *Tricoderma* spp.

Repeated use of pesticides in a frequent manner makes field unfit for agricultural practises Agrochemicals accumulation in the environment is major concern for growers as well as environmentalist. Unused pesticides solution having organic compounds run off directly into the soil becomes worrying situation. These xenobiotics exert harmful consequences to human health. Moreover, these chemical are responsible for decreasing population of microbiome.

The microbiome in the soil helps to fight against pathogens and promote growth and development of plants. Removals of pesticides become cumbersome for scientific community. Conventional treatment appears inefficient (Badawy *et al.,* 2006). *Trichoderma* are able to biodegrade toxic pollutant efficiently (Harman *et al.,* 2004b; Cao *et al.,* 2008). Extracellular enzymes system of the fungi and their catalytic reaction help to degrade toxic aromatic compounds. *Trichodermaviride* was reported most efficient among tested fungi for the degradation of chlorpyrifos and photodieldrin (Tabet and Lichtenstein 1976; Mukherjee and Gopal 1996). Integrated management strategy having *Trichoderma* spp. are combined with pesticides help in remediation of contaminated sites and reducing the chemical load for clean environment.

It is concluded that BCAs *Trichoderma* having complicated interactions between advantageous microbes, established a relationship among plants, pathogens and the soil ecosystem. Fungicides control pathogens effectively, but they pollute soil and water causing harm to human health. For the protection of plants and their crop yield

Trichoderma spp. is best and safer option. Recent advancement of modern techniques and less expensive methods to protect plants and increase crop yield have drawn the attention of growers. Genetic manipulation offers opportunity to achieve improve biocontrol efficacy.

The application of *Trichoderma* metabolites help in protection of crop, by host defence inducers and antibiotics. There is an availability of numerous technologies for environment cleaning, each having its advantages and limitations for the treatment of specific pollutants. Mycoremediation is an innovative approach having a potential to diminish numerous environmental contaminants problems.

The *Trichoderma* are diverse species are tolerant to wide range of refractory pollutants including HMs, pesticides, and polyaromatic hydrocarbons. They are safe, environment friendly and can be easily used by farmers. However, it needs more work to be done to develop cost-effective, stable, and easy to apply formulations.

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