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A REVIEW ON MYCORRHIZA-MYCOPARASITE INTERACTIONS IN THE RHIZOSPHERE

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Abstract

Mycorrhiza is well known for its positive interaction on host plants by improving plant nutrient uptakes. However, there is not only host and Arbuscular Mycoorhizal Fungi (AMF) interaction in soil rhizosphere. There are several reports reveling that other biotic interaction in soil specifically with AMF is crucially important. Interctaion of AMF with soil bacteria and fungi may have an important role on function of AMF. In this review a brief description and impact of mycorrhiza-myciparasite interaction in soil rhizosphere.
Key words: Mycorrhiza, Mycorparasitism, Plant interaction, Soil rhizpsphere

Introduction

In modern agriculture, application of beneficial microorganisms has become a more reliable and alternative source to reduce the application of pesticides, (Brimmer & Boland, 2003). Several studies demonstrates the important role of beneficial microorganism like arbuscular mycorrhizal (AM) fungi, *Pseudomonas* species, *Trichoderma* species etc. in plant growth promotion, improving plant health, productivity (Harman *et al*., 2004; Whipps, 2004; Avis *et al*., 2008) and also the soil quality (Schloter *et al*., 2003; Rillig & Mummey, 2006).

AM fungi is considered among the most primitive and most common symbiotic microorganisms in rhizosphere colonizing over 80% of terrestrial plants (Smith & Read, 2008). These fungi profit the plants with water and nutrients (mainly phosphorus) in exchange for carbon (Smith & Read, 2008) and there are some of the studies that support the role of AMF in drought avoidance (Ru´ız-Lozano and Azcón, 1995), and also in disease resistance (Pozo *et al*., 1999; Conrath *et al*., 2006).

AM fungi establish intraradical colonization to the host and may extend its mycelium biomass into the rhizosphere and can produce over 100m hyphae g^{-1} of soil in some ecosystems (Miller *et al*., 1995; Olsson et al., 1999). The extraradical hyphal network is a complex linkage network among roots and plays an important role in soil nutrients uptake (Miller & Jastrow, 1990; Rillig & Mummey, 2006; Selosse & Duplessis, 2006). Therefore the possibilities of other soil microbes associated with this mycelium cannot be ignored. The soil microbes present in the rhizosphere have a direct affects on development and function of AM symbiosis (Gryndler 2000). In soil rhizosphere, saprotrophic fungi are important factor as they have a major contribution in microbial biomass to the soil. There is a very fine network of mycelia extended all over the mineral soil to facilitate substrate collection (Wainwright 1992; Dix and Webster 1995).

Therefore it is important to understand the possible parasitism of mycelium in AMF. The possibilities of parasitism of AM fungi in soil is because they produce a large biomass (in the form of hyphae) in rhizospheric soil (Olsson 1999; Green *et al*.,1999), including nutrients and fatty acid-rich structures (Olson 1999; Olsson & Johnson, 2005) that is an important substrate source for microorganisms. A considerable efforts has been made to understand the AMF-bacterial interaction in rhizospheric soil (Hodge, 2000; Johansson et al., 2004; Rillig *et al*., 2006) including mycorrhiza-helper bacteria (Garbaye,1994), and also consumption of mycelium by grazers (Klironomos *et al*., 1999; Johnson *et al*., 2005; Jonas *et al*., 2007) but a very few studies on AMF and other fungal interaction in rhizospheric soil has been studied (Paulitz and Menge, 1986; Martinez *et al*., 2004; Chandanie, 2005; Purin and Rilling, 2007).

Mycoparasitism (Fungal-fungal interaction)

Parasitism, a common symbiotic relationship between two microorganisms in which one species benefits for nutrient, growth and reproduction to the harm of the other species. Fungi are widely distributed in environment and can grow in extreme environments such as deserts or deep sea sediments or areas with high salt concentrations as well as in ionizing radiation. Therefore, a continuous struggle in the form of parasitism occurs between fungal organisms to occupy the same habitat in the environment. Fungi inhabit a broad range of environmental niches and, due to their nutritional versatility, perform many essential processes like nutrient recycling and decomposing in global ecosystems. In their natural environment, fungi closely interact with other organisms such as other fungi, bacteria, plants and animals. Interspecific fungal interactions may be mediated upon contact or even at a distance and may include processes like antagonism and mycoparasitism to defend the living space.

Mycoparasitism, term commonly used to indicate the interrelationships of fungus parasite and fungus host (Barnett, 1963) and known as a major mechanism in the biocontrol processes (Howell 1987). In mycoparasitism, one fungus attack on thallus of another fungus, followed by utilizing its nutrients. Sometimes hyperparsitism term used to describe the parasitic behavior of one fungus to other. Mycoparasitism can be divided into: (a) biotrophic and (b) necrotrophic (Barnett and Binder, 1973).

In biotrophic mycoparasitism, parasite develop on living instead of a dead host structure while in necrotrophic mycoparasitism the fungal relationship results in death and destruction of the host thallus (Viterbo *et al*., 2007). Necrotrophic mycoparasitism is most common, most aggressive and having a wide range of host. The activity of parasitic fungi on host fungi is very severe. It produces antibiotics, hydrolytic enzymes or toxin that can cause the

instant death or destruction of host fungi. In biotrophic mycoparasitism, host range is restricted and produces a specialized network or structure for absorbing nutrients from their host fungi (Manocha and Sahai 1993).

This parasitic relationship between two fungi can play a significant role in biocontrol of different fungal generated plant diseases. The most common pathogen targets are *Fusarium* sp., *Pythium* and *Rhizoctonia*. Several non pathogenic strains of *Fusarium* and *Pythium* are well characterized for their biocontrol activity against their pathogenic strains (Larkin and Fravel, 1999). Similarly mutualistic symiotic associated mycorrhizal cultures has also demonstrated their biocontrol activity against pathogenic fusarium strains (St Arnaud *et al*., 1997).

Mycoparasitism of Arbuscular mycorrhizal fungi

Over 80% of terrestrial plants are capable of symbiotic association with AM fungi. AM fungi are the members of the zygomycetes and in present classification these all are placed under order Glomales. AM association mainly influence plant nutrient availability that leads to improved growth and productivity of plants and also having a major role in change in physico-chemical properties of soil ecosystem (Allen, 1991; Rillig, 2004).

Interaction of AM with plant root is a mutualistic symbiotic association. AM helps to plants in nutrient uptake especially phosphorus and it is also assumed that it may influence the plant's resistance to invading pathogens and in return plant supplied carbon to the fungi on which it entirely depends for growth and multiplication. (Newsham *et al*., 1995; Smith and Read, 2008). There are several evidence that supports the increased tolerance for pathogenic infections in plants where AM fungi supplying a larger amounts of nutrients (e.g. *Glomus intraradices* and *Glomus mosseae*) (Bodker *et al*., 2002; Karagiannidis *et al*., 2002).

Parasitism in fungi is considered as an evolutionarily and one of the old mode of interaction (Hass *et al*., 1994). In soil, AMF parasitism is an important interaction and it is intensively studied for the Glomeromycota phylum. However, there are some groups of fungi are known to be affected by parasites, i.e. Oomycetes (Inbar *et al*., 1996; Siwek *et al*., 1997; Ali-Shtayeh & Saleh, 1999), Ascomycetes (Benyagoub *et al*., 1998) and Basidiomycetes (Gao *et al*., 2005). Some examples of mycorrhiza mycoparasitism interactions are listed in table 1.

There are several studies supporting the intracellular occurrence of fungi but these studies merely supporting their effects on any fitness parameter. Therefore, a clear evidence of parasitism is missing. However there are few reports that extended this research to measure the influence of fungal invasion on some AMF fitness parameters. There are both positive and negative reports on plant growth and health of AM-mycoparasitism (Chandanie *et al*., 2005, 2009; Martinez *et al*., 2004). in vitro culture study by Rousseau *et al*. (1996) reported that *Trichoderma harzianum* colonized all extraradical structures by penetrated the thick host wall (i.e. spores and hyphae) of AM fungi through local hydrolysis of the wall polymers. However, in the intraradical phase of the AM symbiosis such observations were not reported. The impact of this parasitism exhibited both results i.e. reduced germination (Sylvia & Schenck; 1983) and no effect on spore germination (Paulitz & Menge, 1984) whereas both studies supports that there is no effect on root colonization and sporulation by the mycorrhizal fungus. These contradictions in results may be due to different species and environmental conditions.

Mechanism involved in mycorrhiza- mycoparsite interaction

There are two types of parasitic fungi i.e. biotrophs (the host fungus remains alive) and necrotrophs (parasitism results in death of the host fungus) and interaction range from close contact to hyphal disruption (Jeffries, 1995). There are several mechanisms like coiling of parasitic hyphae around host hyphae, physical damage and lysis of host hyphal walls, and disruption of cell organelles (Dix & Webster, 1995) which may involve in this kind of interaction. On the other hand, the formation of stable interfaces seems to be more common in biotrophic parasitism, where absorption of nutrients does not lead to host death. The formation of haustorium during invasion of host mycelium is an example of common evidence of these interfaces (Jeffries, 1995). Study on AM- *Trichoderma* myco parasitism reports that mycelium of the AM fungus acts as a channel for the entry of *T. harzianum* into the plant roots. This phenomenon occurred through a multistep extraradical hyphae and spores invasion process involving contact, surface attachment and penetration, and its subsequent extension into the IRM (i.e. intraradical hyphae and vesicles) before exiting in the root cells (De Jaeger *et al*., 2010).

Till date, study of mycorrhiza-mycoparasitism is very limited therefore in near future there are several mechanism that needs to be explored for better understanding of AMF-mycoparasitism

Table 1 : Various studies on AMF and its positive parasitism with other fungi

Glomus species	Parasitism with	Reference
Glomus macrocarpus	*Pythium-like fungus*	Ross & Ruttencutter (1977)
Gigaspora gigantea	*Pythium-like fungus*	Ross & Ruttencutter (1977)
Glomus epigaeus	*Acaulospora pseudolongissima*	Daniels & Menge (1980)
Glomus fasciculatus	*H. fuscoatra*	Daniels & Menge (1980)
Gigaspora gigantea	*Isolated -31 from AMF spores*	Lee & Koske (1994)
Glomus intraradices	*Trichoderma harzianum*	Rousseau *et al*. (1996)
Glomus intraradices	*Fusarium oxysporum* f. sp. dianthi	St Arnaud *et al*. (1997)

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