Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; SP1: 281-284

Amandeep Singh
Assistant Professor, Department of Agriculture, Baba Farid College, Deon, Bathinda, Punjab, India

Rajinder Kumar
Assistant Professor, Department of Agriculture, Baba Farid College, Deon, Bathinda, Punjab, India

Dr. Daljeet Singh
Professor, Department of Plant Pathology, P.A.U, Ludhiana, Punjab, India

Correspondence
Amandeep Singh
Assistant Professor, Department of Agriculture, Baba Farid College, Deon, Bathinda, Punjab, India

(Special Issue- 1)
2nd International Conference
"Food Security, Nutrition and Sustainable Agriculture - Emerging Technologies"
(February 14-16, 2019)

Mycorrhizal fungi as biocontrol agent for soil borne pathogens: A review

Amandeep Singh, Rajinder Kumar and Daljeet Singh

Abstract
Arbuscular mycorrhizae fungi (AMF) are the symbiotic fungi that predominate in the roots and soils of agricultural crop plants. The AMF form beneficial symbioses in most terrestrial ecosystems and crop production systems. 90 per cent of land plant species are colonized by one or more of the mycorrhizal fungi species ranging from flowering to non-flowering plants, while only a few plant families do not form this association. The relationship between mycorrhiza and plant is very widely spread among terrestrial vascular plants. The AMF must have a host to complete its life cycle and this association has been found to be mutually beneficial; thus, the fungus assists the plant in mineral nutrients uptake, while the plant supplies the fungus with carbon as a result of this relation. The negative-antagonistic interaction of AMF with various soilborne plant pathogens is the reason for their use as a bio-controlagents. Many workers have observed an antagonistic effect of AMF against some fungal pathogens as the following mechanism involved like Enhanced plant nutrition uptake, Damage compensation, Competition for colonization or infection sites, Anatomical and morphological changes in the root system etc.

Keywords: AM fungi, colonization, bio-control, soil borne pathogens

Introduction

Biological control of plant pathogens is the key practice in the sustainable agriculture which strives to minimize the use of synthetic fungicides and to use as alternative management strategy to control soil borne pathogens (Barea and Jeffries 1995). Biocontrol agents can be defined as directed, accurate management of the common components of the agriculture ecosystem against pathogens (Azcon-Aguilar and Barea 1997) [1]. Number of biocontrol agents are commercially employed these days such as *Pseudomonas fluorescens*, *Bacillus subtilis*, *Trichoderma harzianum*, *T. viridae* and Mycorrhizal fungi (*Glomus* spp.), *Agrobacterium radiobacter* strain 84 and K1026 etc. for soil borne pathogens. Among them, use of mycorrhizal fungi as biocontrol agent gained importance in integrated disease management programs. Mycorrhizal fungi are a major natural occurring component of soil ecosystem and found associated with roots system of more than 80 per cent of all terrestrial plant species (Including many agronomically important species (Harrier and Watson 2004) [15]. A symbiotic association of fungus and roots was discovered by Franciszek Kamienski (1881) in *Monotropa hypopitys*. The term 'mycorrhiza' coined by Professor Albert Bernhard Frank in 1885. The Mycorrhizal fungi occur widely in legumes (Bargali 2011) [6] and number of forage crops under different ecosystems (Souchie *et al.* 2006) [30]. Until recently Mycorrhizal fungi were clasifies as members of Zygomycota, but analysis of 18S ribosomal RNA shows clearly that Mycorrhizal fungi share common ancestry with Ascomycota and Basidiomycota. So they have been assigned to a new monophyletic group- the Glomeromycota (Scheussler *et al.* 2001). Mycorrhizal fungi is known to protect the plants against several soil borne pathogens like *Fusarium, Pythium* spp., *Verticillium, Ralstonia, Macrophomina* etc. (Davis and Menge 1980) [10]. The present study emphasizes on the role of mycorrhizal fungi in management of soil borne pathogens.

Types of Mycorrhizal fungi

Mycorrhiza was derived from two Greek words namely 'mycos' and 'rhiza' meaning 'fungus' and 'roots' respectively (Kirk *et al.* 2001; Trappe 2005) [18]. Mycorrhiza is a symbiotic mutualistic relationship between fungus and plant roots. The host receives the mineral nutrients from outside the root depletion zone through fungal mycelium, while the fungal counterpart obtained photosynthetically produced carbon compound from the host (Smith and Read 2008) [29, 35]. There are two major groups of mycorrhiza based on its penetration inside the roots of host plant namely Endomycorrhiza and Ectomycorrhiza.

Ectomycorrhiza

These are most common in ornamental and forest species of trees in family Pinaceae, Myrtaceae, Saliceae and Fagaceae (Shalini *et al.* 2000) [27]. Ectomycorrhizal fungi have mentle and hartig netswhich is a distinguishing feature of this association. These hartig nets develop between the cortical cells of the roots without penetrating them and provide a surface contact between these two symbionts (Peterson *et al.* 2004) [23].

Endomycorrhiza

Endomycorrhizal represent group of fungi associated with most agricultural crops and provide biological protection against soil borne diseases (Smith and Read 2008) [29, 35]. They are found in many important crop species (Mungbean, grape, soybean, rice and cotton) and horticultural species (Roses, petunia and lilies) (Peterson *et al.* 2004) [23]. Endomycorrhizal fungi penetrated the cortical cells of the roots of a plant and colonized them.Mostly the members of endomycorrhiza group known as arbuscular mycorrhizae (AM) due to the formation of arbuscules (Kaur *et al.* 2014) [17]. As the name indicated the VAM fungus produced two types of structures i.e. Arbuscules (They were highly branched structures formed within a cell and served as a site for major metabolic exchange, occurred between the plant and the fungus) and Vesicles (sac-like structures, emerged from hyphae and served as storage organs for lipids). The symbiotic association of AMF and plant roots has been considered the oldest symbiosis as it took more than 500 million years for evolution (Redecker *et al.* 2000) [24] Endomycorrhizal association accounts for 80 per cent of the total mycorrhizal associations among agricultural crops.

Other types of mycorrhizal fungi include (Ecto-endo mycorrhizal, Ericoid mycorrhizal, Monotropoid mycorrhizal, Arbutoid mycorrhizal and Orchid mycorrhizal) (Tahat *et al.* 2010) [22].

Potential as Biocontrol agents

Soil borne pathogens were controlled by using several agricultural methods like resistant cultivar seed certification use of fungicides and crop rotation etc. there are many problems associated with controlling pathogens with long term persistant surviving structures due to difficulties in reducing the pathogen inoculum (Azcon-Aguliar and Barea 1997) [1]. So now many workers were trying to use alternate approach based on either manipulating or adding microorganisms to enhance plant protection ad gainst pathogens (Grosch *et al.* 2005) [14]. The protective effect of mychorrhizal symbiosis against soil borne pathogen has been tested by many workers Schonbeck (1979) [31], Bagyaraj (1984), Smith (1987), Erman (2011) [12], Tahat (2008) [33] etc. They concluded that AM association can reduce the ill-effects of soil borne pathogens through following mechanisms *viz*., enhanced plant nutrition uptake, damage compensation of plant, competition for infection or colonization sites, Anatomical and morphological changes in the root system and microbial changes in rhizosphere.

Mechanisms involved in action of AM Fungi

Enhanced plant nutrition uptake

The enhanced nutritional status of plant mainly due to the root colonization of AM fungi which results in more vigorous growth of plants and increased in tolerance or resistance of plants to pathogens attack (Singh *et al.* 2017) [28]. This is primarily achieved by the hyphal network of fungi which takes up the nutrients from soil and transported to the plants in exchange for carbon. The spores in the soil germinate and produce infection hyphae which spread in the whole root system of plant. Depend upon the plant species and AM fungal species involved in the symbiosis, root colonization by AM fungi can increase or decrease the P uptake and other mineral nutrients like Ca, Cu, Mn and Zn (Harrier and Watson 2004) [15].

Damage compensation

It is suggested that AM fungi enhanced the P uptake and tolerance of plants to soil borne pathogens by the compensating for the loss of root functional and biomass caused by soil borne pathogens (Linderman 1994) [20]. It was also favored the increase in surface area and development of root hairs, enhanced the absorbtive capacity of roots also one of the compensatory mechanisms. This illustrated the indirect contribution of AM fungi in biological control of soil borne pathogens (Tahat *et al.* 2010) [22].

Competition for colonization or infection sites

There will be direct competition for space between AM fungi and soil borne pathogens to colonize the roots or to cause infection at a time. It was found that Phytophthora unable to penetrate in the roots containing arbuscules in cortex cells (Cordier *et al.* 1998) [9]. Although, AM fungi and pathogens are colonizing the same host tissues, but they develop within root cortical cells. The presence of arbuscules in plants also lowered the infection sites for soil borne pathogens (Vigo *et al.* 2000) [36].

Anatomical and morphological changes in the root system

Root morphology system can be altered due to the colonization of root by AMF (Tahat *et al.* 2008) [33]. Roots colonized by AMF are more highly branched compared to non-colonized plants and also the adventitious root diameters are larger (Berta *et al.* 1993) [7], which can provide more infection sites for a pathogen (Hooker *et al.* 1994) [16]. Dugassa *et al.* (1996) [11] found that the infection of tomato and cucumber by *Fusarium* wilt might slow down due to the morphological changes in the root cells of the endodermis of AM plants which include lignifications incensement. The raising lignifications may protect the roots from penetration by other pathogens, while elevating of phenolic metabolism within the host plant (Miranda, 1996). The colonization of tomato root by *Glomus mosseae* lead to a bigger root size and more branching which increase the number of root tips, length, surface area and root volume (Tahat *et al.* 2008) [33].

Competition for host photosynthates

The growth of AMF and root pathogen depends on the host photosynthates and they compete for the carbon compounds received by the root (Smith and Read 1997) [25]. When AMF have primary access to the photosynthates, the higher carbon demand may inhibit the pathogen growth (Linderman 1994) [20]. AMF is dependent on the host plant for carbon source. 4-20% net photosynthates of host are transferred to the fungus; nevertheless, there is only a limited data to support this mechanism (Smith and Read 2008) [35].

Enhance tolerance to heavy metals (bioremediation)

The effect of AMF plants on trace elements uptake was reported (Clark and Zeto 2000). The AMF have higher shoot concentrations of copper (Cu) and zinc (Zn) when grown in soil with low concentration of these elements. Copper and zinc concentrations increased in leaves of AM soybean plants compared to nonmycorrhizal plants. Sulfur acquisition was enhanced in sorghum colonized by *Glomus fasciculatum* compared to non-colonized plants (Raju *et al.* 1990) [26]. Boron content was increased in AM maize shoot in acidic and alkaline soils while the acquisition of calcium (K), sodium (Ca) and magnesium (Mg) was also increased compared to the non AM *Gigaspora gigantea* soybean plants in low Phosphorus. At the same time *Gigaspora gigantea* colonized maize plant decreased (K) and Ca but increased Mg acquisition (Lambert *et al.* 1979) [19]. Aluminum (Al) acquisition toxicity was lower in AM switch grass grown in acidic soil compared to non AM plants (Clark 1997) [8].

The interaction between mycorrhizal fungi and other soil organisms are complex and often poorly understood; they may be inhibitory or stimulatory (Fitter and Garbaye 1994) [13]. The PGPR interact with mycorrhiza in the mycorrhizosphere. Inoculation of *Glomus faciculatum* has shown a positive influence on actinomycetes population in tomato rhizosphere. The survival of *Azotobacter paspali* increasedin mycorrhizosphere (Barea *et al.* 2002b) [4]. Higher bacterial population and number of nitrogen fixer such as streptomycin were reported and it has been detected that plants in the presence of AMF and bacteria produced more phytohormones (Secilia and Bagyaraj 1987) [32].

The relationship between Phosphate-Solubilizing Bacteria (PSB) and AMF is well reported (Barea *et al.* 2002a) [2]. The PSB can survive longer in root's mycorrhizosphere. A plant with higher concentration of P benefits the bacterial symbiont and nitrogenase functioning (Barea *et al.* 1993) [3]. Dual inoculation of AMF and PSB significantly increased microbial bioma**ss** and N and P accumulation in plant tissues (Barea *et al.* 2002a, b) [2, 4]. Mycorrhizae increased nitrogen nutrition in plant by facilitating the use of nitrogen forms that are difficult for mycorrhizal plants to exploit. Many rhizobium strains improve processes involved in AM formation (mycelia growth, spore germination) (Barea 1997) [5].

References

1. Azcon-Aguilar C, Barea JM. Applying mycorrhiza biotechnology to horticulture: Significance and potentials. Sci. Hortic. 1997; 68:1-24.
2. Barea JM, Toro M, Orozco MO, Campos E, Azcon R. The application of isotopic (^{32}P and N^{15}). Dilution techniques to evaluate the interaction effect of phosphate solution rhizobacteria, mycorrhizal fungi and rhizobium to improve agronomic efficiency of rock phosphate for legume crops. Nutr. Cycle. Agroecosyst. 2002a; 63:35-42.
3. Barea JM, Azcon R, Azcon-Aguilar C. Mycorrhiza and crops. Adv. Plant Pathol. 1993; 9:167-189.
4. Barea JM, Azcon R, Azcon-Aguilar C. Mycorrhizosphere interactions to improve plant fitness and soil quality. Antonie Van Leeuwenhoek. 2002b; 81:343-351.
5. Barea JM. Mycorrhiza-Bacteria Interactions on Plant Growth Promotion. In: Plant Growth Promoting Rhizobacteria, Ogoshi, A., K. Kobayashi, Y. Homma, F. Kodama, N. Kondo and S. Akino (Eds.). OECD Press, Paris, France, 1997, 150-158.
6. Bargali K. Screening of leguminous plants for VAM association and their role inrestoration of degraded lands. J Ame Sci. 2011; 7:7-11.
7. Berta G, Fusconi A, Trotta A. VA mycorrhizal infection and the morphology of root systems. Environ. Exp. Bot. 1993; 33:159-173.
8. Clark RB. Arbuscular mycorrhizal adaptation, spore germination, root colonization and host plant growth and mineral acquisition at low pH. Plant Soil 1997; 192:15-22.
9. Cordier C, Pozo MJ, Barea JM, Gianinazzi S, Gianinazzi-Pearson V. Cell defense responses associated with localized and systemic resistance to Phytophthora parasitica induced in tomato by an arbuscular mycorrhizal fungus. Mol. Plant Microbe Interact, 1998; 11:1017-1028.
10. Davis EA, Menge JA. Influence of *Glomus faciculatum* and soil phosphorus on *Phytophthora* root rot of citrus. Phytopathol 1980; **70**:447-52.
11. Dugassa GD, Von Allen H, Schonbeck F. Effect of Arbuscular Mycorrhiza (AM) on health of *Linum usitatissimum* L. infected by fungal pathogen. Plant Soil 1996; 185:173-182.
12. Erman M, Demirb S, Ocakc E, Tufenkc SE, O'guza F, Akkoprub A. Effects of Rhizobium, Arbuscular Mycorrhiza and whey applications on some properties in 83 chickpea (*Cicer arietinum* L.) under irrigated and rainfed conditions on yield components, nodulation and AMF colonization. Field Crops Research. 2011; 122:14-24.
13. Fitter AH, Grabaye J. Interactions between mycorrhizal fungi and other soil organisms. Plant Soil 1994; 159:123-132.
14. Grosch R, Lottmann J, Faltin F, Berg G. Use of bacterial antagonists to control diseases caused by *Rhizoctoniasolani*. Gesunde P flanzen, 2005; 57:199-205.
15. Harrier LA, Watson CA. The potential role of Arbuscular Mycorrhizal (AM) fungi in the bio protection of plants against soil-borne pathogens in organic and/or other sustainable farming systems. Pest Manage. Sci. 2004; 60:149-157.
16. Hooker JE, Jaizme-Vega M, Alkinson D. Biocontrol of Plant Pathogen Using Arbuscular Mycorrhizal Fungi. In: Impact of Arbuscular Mycorrhizas on Sustainable Agriculture and Natural Ecosystems, Gianinazzi, S. and H. Schhepp (Eds.). Birkhauser Verlag, Basle, Switzerland, 1994, 191-209.
17. Kaur R, Singh A, Kang JS. Influence of Different Types Mycorrhizal Fungi on Crop productivity. Curr Agric Res. 2014; J**2**:51-54.
18. Kirk PM, Cannon PF, David JC, Stalpers JA. *Ainsworth and Bisby's dictionary of the fungi*, 9th edn. Wallingford, UK: CABI Publishing, 2001.

19. Lambert DH, Baker DE, Cole HJ. The role of mycorrhizae in the interactions of phosphorus with zinc, copper and other elements. Soil Sci. Soc. Am. J. 1979; 43:976-980.
20. Linderman RG. Role of VAM Fungi in Biocontrol. In: Mycorrhizae and Plant Health, Pfleger, F.L. and R.G. Linderman (Eds.). The American Phyto pathological Society, St. Paul, MN., USA., ISBN: 0-89054-158-2, 1994, 1-27.
21. Morandi D. Occurrence of phytoalexins and phenolic compounds in endomycorrhizal interactions and their potential role in biological control. Plant Soil. 1996; 185:241-251.
22. Tahat MM, Kamaruzaman, Sijam, Othman R. Mycorrhizal Fungi as a Biocontrol agent. Plant pathology journal. 2010; 9:198-207.
23. Peterson RL, Massicotte HB, Melville LH. Mycorrhizas: Anatomy and Cell Biology. NCR Research Press, Ottawa, Canada, 2004, 173.
24. Redecker D, Morton JB, Bruns TD. Molecular phylogeny of the Arbuscular mycorrhizal fungi *Glomus sinuosum* and *Sclerocystis coremioides*. Mycologia 2000; 92:282-85.
25. Smith SE, Read DJ. Mycorrhizal Symbiosis. 2nd Edn., Academic Press, London, UK., ISBN-13: 978-0-12-652840-4, 1997, 605.
26. Raju PS, Clark RB, Ellis JR, Maranville JW. Effects of species of VA-Mycorrhizal fungi on growth and mineral uptake of sorghum at different temperatures. Plant Soil. 1990; 121:165-170.
27. Shalini R, Chamola BP, Mukerji KG. Evolution of Mycoorhiza. In: Mycorrhizal Biology, Mukerji, K.G., B.P. Chamola and J Singh (Eds.). Plenum Publishers, USA. 2000.
28. Singh N, Singh D, Singh N. Effect of *Glomus bagyaraji* inoculation and phosphorus amendments on Fusarium wilt of chickpea. Agric Res J. 2017; 54:236-43.
29. Smith SE, Read DJ. Mineral Nutrition, Toxic Element Accumulation and Water Relations of Arbuscular Mycorrhizal Plants. In Mycorrhizal Symbiosis. 3rd Edn., Academic Press, London, ISBN-10: 0123705266, 2008, 145-148.
30. Souchie EL, Orivaldo J, Saggin-Junior OJ, Silva EMR, Campello EFC, Azcon R *et al.* Communities of P-solubilizing bacteria, fungi and Arbuscular-mycorrhizal fungi in grass pasture and secondary forest of Paraty. RJ-Brazil. An. Acad. Bras. Cienc. 2006; 78:183-193.
31. Schonbeck F. Endomycorrhiza in relation to plant diseases. In: Schipper B and W Gams (eds) *Soil-borne plant pathogens.* Academic Press, London, New York, San Francisco. 1979, 271-280.
32. Secilia J, Bagyaraj DJ. Bacteria and actinomycetes associated with pot cultures of vesicular-arbuscular mycorrhizas. Can. J Microbiol. 1987; 33:1069-1073.
33. Tahat MM, Kamaruzaman S, Radziah O, Kadir J, Masdek HN. Response of (*Lycopersicum esculentum* Mill.) to different arbuscular mycorrhizal fungi species. Asian J Plant Sci. 2008; 7:479-484.
34. Trappe JM. AB Frank mycorrhizae: the challenge to evolutionary and ecologic theory. *Mycorrhiza* 2005; 15:277-81.
35. Smith SE, Read DJ. Mycorrhizal Symbiosis. 3rd Ed. Academic Press, London, UK, 2008, 800.
36. Vigo J, Norman J, Hooker J. Biocontrol of the pathogen *Phytophthora parasitica* by arbuscular mycorrhizal fungi is a consequence of effects on infection loci Plant Pathology. 2000; 49:509-514.