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## **Mycorrhizal Fungi and Abiotic Environmental Conditions Relationship**

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### **ABSTRACT**

Arbuscular mycorrhizal fungi (AMF) are associated with the roots of over 80% terrestrial plant species. Mycorrhizal fungi are critical and important microbes for plant growth and survival. It is generally accepted that environmental conditions that favor host plant growth tend to maximize mycorrhizal infection and sporulation. Mycorrhizal colonization is known to induce many morphological, physiological and biochemical changes in host plants. Environmental factors and soil conditions influence the occurrence of mycorrhizal associations in ecosystems but it is hard to examine the direct impacts of these factors on mycorrhizal fungi because they rarely occur in nature without a host and members of the glomales cannot be grown axenically. Among the biofertilizers mycorrhizal fungi form the most significant group of soil microorganisms. This review addresses the main abiotic conditions which interacted with mycorrhizal fungi were discussed which included (soil temperature, soil acidity, crop rotation, fertilizer and organic matter, drought stress and soil moisture, pesticides, heavy metals and salt stress).

**Key words:** Abiotic mycorrhiza, soil, pesticides, temperature, pH, fertilizer

### **INTRODUCTION**

Arbuscular mycorrhizal fungi are members of the kingdom fungus and they are the most important component of natural resource and agricultural (Smith and Read, 2008; Tahat *et al.*, 2010a,b). In *Monotropia hypopitys*, Franciszek Kamienski in 1881 describe the asymbiotic association of fungus and roots. The fungus-root (Myco-rhiza) relationship had initiated worldwide studies interest by the Polish botanist Frankin 1885. The peculiar association between root trees and ectomycorrhizal fungi was gave the name "MYCORRHIZA" by Frank in 1885 (Koide and Dickie, 2002). Ninety percent plant species are colonized by one or more of mycorrhizal fungi species this included flowering and nonflowering plants while only a few plant species do not form this association (Harrier and Sawczak, 2000). There have been a few studies about the ability of mycorrhizal fungi to control bacterial wilt diseases (Hayward, 1991; Tahat and Sijam, 2010).

Mycorrhizal fungi are critical and important microbes for plant growth and survival (Smith and Read, 2008; Tahat *et al.*, 2008c). The viability propagules and the spore production of AMF in soil is affected by a range of biological and non-biological factors (Lee and Koske, 1994; Rousseau *et al.*, 1996; Tahat *et al.*, 2008c). Soil disturbance reduces the viability of spores inoculum and hyphae (McGee *et al.*, 1997). Since, AM fungi cannot grow saprophytically

(Tahat *et al.*, 2008b), propagules become very senescent with time if deprived of a living plant host. Therefore, the objective of this review was to illustrate the main abiotic factors which can play a significant role in mycorrhizal fungi usage as a bio-fertilizer under different environmental conditions.

## SOIL TEMPERATURE

The effect of soil temperatures on mycorrhizal function was reported (Smith and Roncador, 1986). In *Dichantheium lanuginosum*, *Mimulus guttatus* and *Agrostis scabra*, the increase in plant allocation to AMF, apparent less of temperature adaptation by AMF and differential host response to AMF suggest that AMF could be significant drivers of plant community response to increased soil temperature associated with global change (Bunn *et al.*, 2009). Soil temperature, both as a constant regime and as a stress inducing factor, may alter the physiology of mycorrhizal symbiosis to stimulate greater inoculum production by influencing root morphology and host plant nutrition and growth as well as the general ontogeny of mycorrhizal roots (Hafeel, 2004). VA species mycorrhizal temperature of the environment can be recorded more readily in summer than spring or winter crops. Optimal temperature for germination may be related to the environment to which each endophyte is indigenous (Giovannetti, 2000). It is evident that the effect of temperature on symbiosis varies with the specific host and endophyte. Therefore, more researches are needed if we are to develop uniform and predictable endophyte-host responses. A species that can adapt to wide variations in soil temperatures and also maintain its symbiotic efficiency may have an advantage as an introduced organism (Smith and Roncador, 1986).

## SOIL ACIDITY

Effects of soil pH on AMF have been reported by several investigators (Wang *et al.*, 1993). Little is known to what extent mycorrhizas and their association microflora may create, control and maintain the pH of their environment through exudation (Schwab *et al.*, 1991). Inoculation with *Glomus* sp. increased phosphorus uptake and plant growth when the soil pH was 7.0 or higher (Abbott and Robson, 1985). The relation between VAM and pH depends on soil type, plant species and fungal species (Tahat *et al.*, 2010b). Mycorrhizal fungi vary in their soil pH tolerance; some grow in low pH and others grow after adding amount of lime for soil pH modification (Giri *et al.*, 2003). Soil pH is a critical factor in studying endomycorrhizal fungi ecology. For example, low soil pH has effect on the uptake and movement of phosphorus in rhizosphere and plant nutrient supply mechanisms (Giri *et al.*, 2003).

Wangshuguang (2001) was tested ten AMF strains, including *Glomus epigaeum* (No. 90001), *Glomus caledonium* (No. 90036), *Glomus mosseae* (No. 90107), *Acaulospora* *soo.* (No. 34), *Scutellospora heterogama* (No. 36), *Scutellospora calospora* (No. 37), *Glomus manihotis* (No. 38), *Gigaspora* sp. (No. 47), *Glomus manihotis* (No. 49) and *Acaulospora* sp. (No. 53). He found that strain 34 and 38 were the most tolerant to acidity and these strains showed quicker and higher-rated colonization three to four times more in number of nodules, two to four times more in plant dry weigh, 30 to 60% more in hyphae length and higher soil pH than without VA mycorrhizal fungus. Other strains also could improve plant growth and enhance plant tolerance to acidity. The report was indicated that VA mycorrhizal fungi differed in the tolerance to soil acidity and so did their inoculation effects.

## CROP ROTATION

Crop rotation is a very ancient cultural practice (Howard, 1996). Crop rotation has critical effect on soil microbial communities, soil structure and organic matter (Curl, 1963). The main idea behind crop rotation practice is to disrupt disease cycle (Pierce and Rice, 1998). Few research has been executed to distinguished mycorrhizal fungi community composition and diversity. The AMF spores surveys as a baseline in the field soil to assess the impact of agricultural practices on mycorrhizosphere (Douds and Millner, 1999). Some researchers showed that introduction of leguminous plant for a season into conventional system of maize increased microbial diversity (Bunemann *et al.*, 2004). Agricultural practices management influence AMF communities structure quantitatively and qualitatively (Miller *et al.*, 1995). Crop rotation is known to affect AMF in the field. Crop rotation also affects species diversity (Douds *et al.*, 1999). Crop rotation affected spore population of AMF in another crop-rotation management trial utilizing a maize-vegetable-small grain rotation and chemical fertilizer or organic amendments as sources of mineral nutrients (Douds *et al.*, 1999).

## FERTILIZER AND ORGANIC MATTER

One of the most important mechanisms to understand the effect of VAM on plant root system is the nutrition supply (Davamani *et al.*, 2010). The additional of fertilizer and organic matter improved soil properties such as fertility, water-holding capacity, aggregation, bulk density, hydraulic conductivity the degree of compaction and resistance to water (Franzluebbers, 2002). Mycorrhizas fungal hyphae play great role by binding agents within and between aggregates (Ortas and Lal, 2012). In the mycorrhizosphere, mycorrhizal hyphae may contribute further to the aggregating effect as they grow into small pores and bind soil particles together (Miller and Jastrow, 1990). Bearden and Petersen (2000) reported that mycorrhiza played a significant role in the formation of aggregates and aggregate stability. Mycorrhizal polysaccharide shown to bound the soil particles (Tisdall, 1994). Water-stable soil aggregates were correlated positively with root and arbuscular mycorrhizae soil mycelium development (Celik *et al.*, 2004). Mycorrhiza have also benefited for the soil rehabilitation, soil ecology and erosion control by stimulating soil (Ortas and Lal, 2012).

Eight years of fertilization of low nutrient soil caused population of *Gigaspora gigantea* to decline and *Glomus intraradices* to increase (Johnson and Pfleger, 1992). Phosphorus is generally considered to be the most important plant-growth factor which can be supplied by mycorrhizal association, because of many biotic and abiotic factors that restrict its mobility in soil (Smith and Read, 2008). Phosphorus fertilizers are known to inhibit colonization of roots and spore production by AMF (Douds and Schenk, 1990). In agricultural soils, a decline in numbers of viable and healthy AM propagules can occur during long weed-free fallows or during rotation with non-mycotrophic plants (Johnson and Pfleger, 1992).

## DROUGHT STRESS AND SOIL MOISTURE

Drought stress results in greater yield loss than any other single biotic or abiotic factor (Ober, 2008; Boyer, 1982). Wheat (*Triticum durum* Desf.) plants colonized with *Glomus mosseae* and *G. monosporum* have greater tolerance to drought than nonmycorrhizal plants. The *Glomus mosseae* and *G. monosporum* plants grown under non water stress had higher nutrient

contents than non AMF plants (Al-Karaki and Clark, 1998). AMF colonization enhanced plant growth under drought stress indirectly through influence the soil moisture retention via glomalin's effect on soil water-stable aggregates although, direct mineral nutritional effects could not be excluded (Wu *et al.*, 2008). Michelsen and Rosendahl (1990) reported that the drought treatment reduced *Acacia nilotica* and *Leucaena leucocephala* seedlings biomass and nodulation. Differences between the plant species were observed with respect to growth improvements due to VAM inoculation and/or phosphorus fertilization under drought stress conditions.

## PESTICIDES

Several interactions between mycorrhizal fungi, their hosts and the environment must be recognized in considering the impact of pesticides (Tu, 1993). Cause and effect can be difficult to determine, because what influences the fungus may thereby indirectly influence the host and vice versa (Schuepp and Bodmer, 1991). An herbicide that severely damages the host will almost certainly damage the mycorrhizae and consequently pesticide effects on soil microbes have been tested mostly in agricultural soils (Atlas *et al.*, 1978; Tu, 1992). Colinas pesticides have been widely used in forests and forest nurseries against fungal diseases (fungicides), weeds (herbicides) and herbivores (insecticides). According to a questionnaire conducted in 1996 about 1000 kg of pesticides (as active ingredient) have been used each year, of which 42% were herbicides, 40 fungicides and 18% insecticides (Juntunen, 2001). Mycorrhizal fungi grow with the roots of many plants and aid in nutrient uptake. These fungi can also be damaged by herbicides in the soil. One study found that oryzalin and trifluralin both inhibited the growth of certain species of mycorrhizal fungi (Kelley and South, 1978). Roundup has been shown to be toxic to mycorrhizal fungi in laboratory studies and some damaging effects were seen at concentrations lower than those found in soil following typical applications (Estok *et al.*, 1989). Triclopyr was also found to be toxic to several species of mycorrhizal fungi and oxadiazon reduced the number of mycorrhizal fungal spores. Pesticide residues are found in soil and air and in surface and ground water across the nation and urban pesticide uses contribute to the problem (Chakravarty *et al.*, 1987). Pesticide contamination poses significant risks to the environment and non-target organisms ranging from beneficial soil microorganisms, insects, plants, fish and birds. Contrary to common misconceptions, even herbicides can cause harm to the environment. In fact, weed killers can be especially problematic because they are used in relatively large volumes (Moorman, 1989). The best way to reduce pesticide contamination (and the harm it causes) in our environment is for all of us to do our part to use safer, non-chemical pest control (including weed control) methods (MC, 2000).

## HEAVY METALS

Many soils around the world are polluted with heavy metals and are therefore, of limited value for farming purposes (Hildebrandt *et al.*, 2007). AMF could be of particular benefit to plants in relation to alleviating heavy metal (Leyval *et al.*, 2002). Plants growing in heavy metal soils can be colonized by AMF. Recent reviews on this subject are available (Jeffries *et al.*, 2003). The work of Hildebrandt *et al.* (2007) showed that polluted soils contain AMF that are specifically adapted to soil pollution. It has often been stressed that specific AMF spores from heavy metal soils possess enormous potential for phytoremediation. Khan (2003) reported the potential use of AMF in detoxification of heavy metals in environments polluted. It is suggested that AMF are mycobionts that could be exploited in such processes. The research results reported by Val *et al.* (1999), who

used four different species of AMF (*Glomus claroideum*, *Glomus* sp. and *Glomus mosseae*) among these species they suggest that *G. claroideum* isolates shows a potential adaptation to increased metal concentration in soil this species was isolated from the plots planted with receiving the highest dose of metal-contaminated sludge, In the same study the *Glomus* sp. and *G. mosseae* isolates were inhibited strongly by heavy metals which acted mainly by interfering with the growth of the external mycelium and by limiting the production of arbuscules.

## SALT STRESS

Several studies investigating the role of AMF in protection against salt stress (Wang *et al.*, 2004). Salinization is a serious soil problem and it is increasing steadily in several parts of the world, in particular in semiarid and arid areas (Giri *et al.*, 2003; Al-Karaki, 2006). AMF have been known to occur naturally in saline environments (Harinasut *et al.*, 2003; Yamato *et al.*, 2008). The average density of spores in saline areas is reported to be low by some researchers (Barrow *et al.*, 1997; Carvalho *et al.*, 2001) but not others (Bhaskaran and Selvaraj, 1997; Aliasgharzadeh *et al.*, 2001) observed that *Glomus intraradices*, *G. versiform* and were the most *G. etunicatum* predominant species of AMF in the severely saline soils. Aliasgharzadeh *et al.* (2001) found that the number of AMF spores did not significantly decrease with soil salinity and reported a relatively high spore number (mean of 100/10 g soil). The higher fungal spore production in saline soils may be due to the sporulation is stimulated under salt stress which means that AMF may produce spores at low root-colonization levels in severe saline conditions. This is in contrast to other researchers on saline soils where low or even zero spore population was found in soils with ECe approx. 45 dS m<sup>-2</sup> (Barrow *et al.*, 1997). Salinity, not only affects the host but also the AMF. It can hamper colonization percentage, growth of hyphae and spore germination of the fungus. Numerous researchers have documented the negative effects of salinity on the fungus (McMillen *et al.*, 1998; Jahromi *et al.*, 2008). Colonization of plant roots by some AMF is reduced in the presence of NaCl (Menconi *et al.*, 1995).

Some researchers have reported that the symbiosis results in increased minerals uptake (Tahat *et al.*, 2008a) accumulation of an osmoregulator, an increase in water-use efficiency and photosynthetic rate, suggesting that salt-stress alleviation by AMF results from a combination of biochemical, physiological and nutritional effect (Aliasgharzadeh *et al.*, 2001). Daei *et al.* (2009) demonstrated that the influence of different species of AMF on enhancing plant growth under salinity was observed in the following order: *Glomus etunicatum*>*G. mosseae*>*G. intraradices*. The symbiosis of *Glomus etunicatum* and *G. intraradices* with the Tabasi mutated line resulted in the highest (42.08%) and the lowest (7.55%) increases in wheat dry weight, respectively.

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