

My Corrhiza Assisted Drought Avoidance In Crops

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ABSTRACT

ArbuscularMycorrhizal Fungi (AMF) is widely known for its symbioticassociation with plants that helps in nutrient uptake and also to environmental stress avoidance. There are several mechanisms involved in drought avoidance like biochemical changes i.e. accumulation of osmoprotectants, higher osmotic adjustment capacity and rapid enhancement of different antioxidants that ultimately improve membrane stability. Mycorrhizal inoculation reduces the effect of drought stress in crops by improving growth, yield and nutrient uptake. This review provides an overview on different biochemical mechanisms involved in drought stress tolerance and role of mycorrhiza combating abiotic stress.

Keywords-AM fungi, Drought Stress, Enzymes Osmolytes, Proline,

Introduction

A major farming community of the world is dependent on cereal cultivation for their livelihood. However, as compare to other crops cereal crops required higher amount of water for its growth and development. Continuous cultivation of cereals specifically in developing countries like India leads to overexploitation of ground water. In recent years, a drastic decrease in ground water level has been reported specifically due to rice wheat cultivation system. It is estimated that in coming few decades if overexploitation of water resources in continued, most of the area will be shifted to drought areas. All over the world there is a serious impact of drought on crop yield. However, upto some extent plant system itself having molecular or biochemical changes that can avoid drought stress (Condon et al. 2002).However, prolonged drought stress cannot be defenced by plants and serious

morphological, physiological and biochemical injury occurs. In recent years, microorganisms specifically bacteria and fungi received attention for inoculation in plants (Arzanesh et al. 2011).

Arbuscularmycorrhizal fungi (AMF) known for its beneficial symbiotic association with major community of plants. It is very well known for helping plants in increased nutrient uptakes that ultimately effect plant growth. In recent reports, role of AMF is also reported for its contribution in bioprotection against different plant pathogens and water stress (Jeffries et al., 2012). AMF can alter the plant water relations and avoid injury from water stress in plants (Ruiz-Lozano et al., 1995; Augé, 2001) while in non stressed plants, leaf water potential cannot be influenced by AMF symbiosis. There are several mechanisms involved in AMF induced water uptake of plants like osmotic conductance, improved stomatal sensitivity to leaf, deficit in air vapour pressure and lower leaf osmotic potential for turgor (Sánchez-Blanco et al., 2004).

Mechanism of drought tolerance and water absorption

In rhizospheric soil, AMF colonization with host plant improves the boundary of soil by changing the structural design of roots (Atkinson et al., 1994). Since hyphae of AMF spreaded very wide in soil that ultimately increase the nutrient and water absorption area for host plants. Transport of water by AMF hyphae may range upto 375 to 760 ml (Faber et al., 1991). The modification in host water relations in AMF plants indirectly by improving nutrient availability specifically phosphorous (Safir et al., 1971). Also, many nutrients are directly and indirectly involved in improving and preserve water relations of host plants inclusion (Azaizah et al. 1995).

Fungi are widely known for their significant role in altering soil structure. Fungi helps in tieing of soil aggregates with the help of thread like network (i.e. hyphae) spreaded all over in the soil. Improved soil aggregation helps enhancing soil humidityholding capacity (Hamblin, 1985; Tisdall, 1991; Staddon et al., 2003; Rillig, 2004).

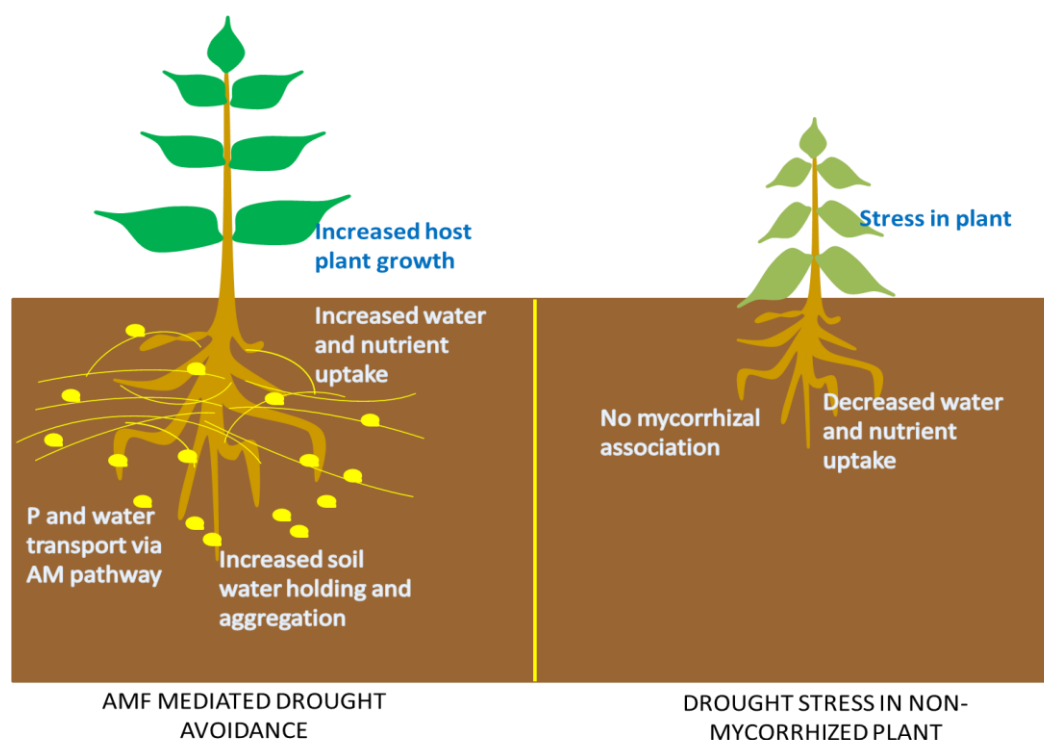


Fig 1:Response of mycorrhized and non mycorrhized plants towards drought stress

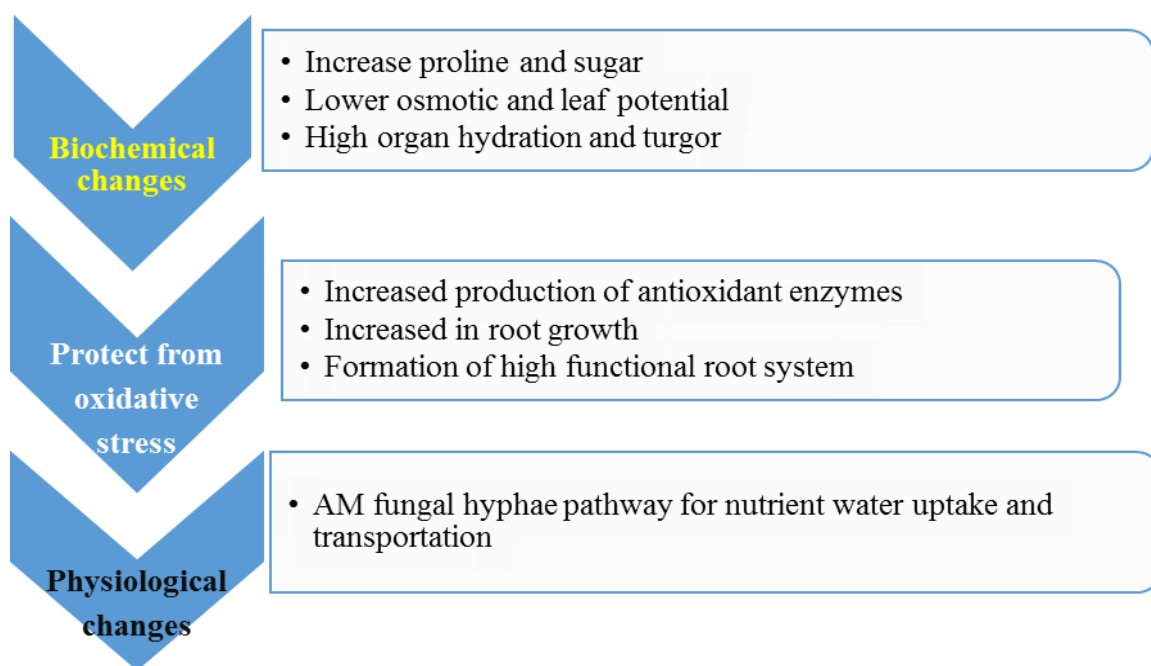


Figure 2. Metabolic changes under drought stress in am plants

Table 1. Role of AMF symbiosis for drought avoidance in crop plants

AMF Species	Crop	Type of Stress	Mechanism	References
<i>Glomusspp</i>	wheat	Drought	Biochemical changes- In mycorrhizal plants total protein, sugar, carbohydrate, amino acids and proline, enhance the activity of peroxidase (POX) and catalase (CAT) which are antioxidant enzymes and having a major role in drought avoidance	Khalafallah and Abo – Ghalia ,(2008)
<i>Funneliformis mosseae</i>	Maize (Zea mays)	Drought	amino acids accumulation, significant increase in trehalose content and higher trehalase activity	Schellenbaum, (1998)

<i>Funneliformis mosseae</i> and <i>Claroideoglomus etunicatum</i>	Maize (<i>Zea mays</i>)	Drought	Enhance nutrient concentration specifically P and Fe concentration in AM inoculated plants and higher grain yield and higher biomass	Miransari et al. (2004)
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Influence of AM fungi on tissue water potential

When there is stressful condition plants water potential are also affected. When AMF inoculated plants are subjected to drought stress an elevated tolerance was reported (Allen and Boosalis, 1983) and also it shows better response against all stress.

Effect on transportation of water

Water transportation is the major phenomenon in the Mycorrhizal plants. The hyphae of Mycorrhiza help in transportation of water from roots to plants. The diameter of hyphae is 2-5 micrometre which can penetrate the minute soil pores those are difficult to get in to root hairs (Sanchez-Diaz and Honrubia 1994). This causes more access to available water and extension in hyphae of Mycorrhiza there are few or no septa. These Mycorrhiza hyphae can act as highway which can transport water from hyphae to plant cell (Allen, 2007). It has been reported that in 10-mm diameter hyphae the water transport was reported around 5.4 ml/h under 0.5 Mpa gradient conditions and it would be bidirectional flow of water (Allen, 2007). The hyphae of Mycorrhiza also contribute the water distribution within rhizosphere by the reverse flow of water from root to Mycorrhizal plants. (Egerton-Warburton et al. 2007).

Role of Aquaporins

Aquaporins are the water protein or tunnel protein that allow or regulate the movement of water passively (Kruse et al. 2006) for the transcellular water flow the aquaporins genes should be unregulated so to increase the permeability of the water in plants (Javot and Maurel

2002). Aquaporins increase the hydraulic conductivities of plant root when there is symbiosis of AM fungus in plants.

Influence of AM fungi on enzymatic activities

When plants are exposed to stress, a rapid production of Reactive Oxygen Species (ROS) and free radicals takes place. ROS are the toxic molecules which have the potential to damage the DNA, lipids and proteins (Miller et.al, 2010). Studies shows that when plant inoculated with AM fungus there is an increased production of superoxide dismutase (SOD), peroxidase and catalase activity that increase proline content (Khalafallah and Abo Ghalia, 2008). The level of superoxidase dismutase, peroxidase and catalase increases in AM plants as compared to nonmycorrhizal one (Khalafallah and Abo Ghalia, 2008) and MDA content and plasma membrane conductivity significantly decreased (Baozhong et al., 2010).

Physiological responses of AM fungus under drought stress.

When the plants are affected with drought stress there is a modification of water in aboveground. The physiological response include the leaf relative water content, stomatal conductance, leaf water potential of leaf and efficiency of Photo system II which will alter by AM symbiosis as compared to Non Mycorrhiza one (Augé 2001; Barzana et al. 2012). Positive modification like increase in rate of exchange of gases, transpiration, and conductance of stomata and rate of photosynthesis in plants inoculated with AM fungi (Khalvati et al. 2005; Lee et al. 2012). ABA is plant hormone which usually increases in drought stress condition but when plants are subjected to AM fungus there will be the ABA level decrease and more in non Mycorrhiza plants (Doubková et al. 2013).

The rate of photosynthesis in plants is directly affected when subjected to drought stress. As the rate of chlorophyll reduces it directly affect the rate of photosynthesis. The low

photosynthesis level impact on plants functions and also leaf orientation of plants shows changes (Anjum et al., 2003b). Similarly the leaf area, effect on stomata especially stomata closure also shows changes. The closing of stomata decline the CO₂ uptake in drought stress. And this CO₂ reduction causes the destruction of photo systems in plants. (Cornic and Massacci, 1996). These changes occur mainly due to one of the depending factor that is chlorophyll. The low rate of chlorophyll automatically declined the photosynthesis activity. These changes are not limited to photosynthesis reduction but reduction in leaf expansion and damaging of photosynthesis machinery has been observed (Fu and Huang, 2001)

As the photosynthesis rate are reduced the cycles are also effected which can take place in plants. The C₃ cycle are also affected, as the rate of C₃ cycle enzymes are reducing. The leaf senescence of the premature can leaf take place in the condition of drought where the rate of photosynthesis is low. This reduction ultimately affects the production of food. The food production is also depending on the photosynthesis rate. If the photosynthesis level has declined the production of food are also decline (Wahid and Rasul, 2005 and Monakhova and Chernyadèv, 2002).

There are several studies shows difference between the mycorrhizal and non mycorrhizal plants in relation to photosynthetic rate. An experiment conducted on drought avoidance in wheat by inoculation of *R. Fasciculatus* reported that the AM inoculated plants performed better as compared to non mycorrhized one. The stomata of the non mycorrhizal plants were closed after four days and the leaf potential in that stage was -1.8 MPa. Contrasting to this statement the mycorrhizal one show positive result as compared to non mycorrhizal plants. In AMF, plants were transpired up to six to seven days. In this leaf water potential was -2.2 to -2.7 which were more negative potential as compared to non mycorrhizal

one (Allen and Boosalis,1983).Therefore, it can be clearly stated that AM inoculated plants perform even well at low water potential.

AMF plants shows positive result with high stomatal conductance in plants. When this rate shows positive result the main factor that is transpiration are also affected. The AMF plants also cause the high transpiration rates and which cause the more photosynthesis in plants. When the rate of photosynthesis increases the internal concentration of CO₂ has been reduced. These changes have observed in AMF plants. (Yang et al., 2014; Zhu et al., 2012).The fixation of carbon in plants also enhanced as the rate of photosynthesis increased. These increments affect the physiology of plants.Zhu et al. (2012) observed the more photosynthesis and more transpiration in maize plants under drought as well as in control condition in response to mycorrhiza and non mycorrhiza plants. The observation of this experiment came to the point that the stomatal conductance in AMF shows better performance as compared to Non AMF. This is due to the mycorrhizal ability to open the stomata so to exchanges of gases takes place. This exchange of gases also affects the rate of transpiration and rate of photosynthesis. (Subramanian et al., 1995).

As the rate of photosynthesis increases in AMF plants, the ability of plants to uptake the water are also increases. This ability of water uptake in plants increases the water use efficiency in plants. This WUE protect the higher tissue of plants. As the process of uptake of water continues the movement of water to evaporative surface begins. This will make the guard cell of the plants more turgid and enable the stomata to open. The opening of stomata helps the exchanges of gases (Nelsen and Safir, 1982). When the exchanges of gases take place the CO₂ entry will occur. This entry of CO₂ not only improves the plants photosynthesis but also improve the plants metabolic and physiologic processes. (Zhu et al., 2011).

The high chlorophyll content of the leaves of AM inoculated plants could also be recognised by the higher rate of photosynthesis. Photosynthetic rate and chlorophyll fluorescence is related to the chlorophyll concentration. Under water stress condition, AMF assist plant to increase carotenoids and avoids photo destruction and photo inhibition of pigments that ultimately helps in protection of photosynthetic apparatus. Carotenoids helps in quenching and deactivation of excited triplet state of chlorophyll (Foyer and Harbinson, 1994) and therefore it is clear that the plants are having symbiotic association with the fungus as it protects the plant under stress conditions.

Conclusion and future perspectives

As there will be a shortage of water due to increased activities of human the level of water will decline and crop production decreases. When plants are subjected to AM fungi, it allows plant to tolerate under drought condition. If there will be less chances of rainfall, AM plants withstand the drought condition and can survive up to several days in the absence of rainfall.

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