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A study on the inoculated root of *Sorghum vulgare* by mycorrhiza under the water stress condition

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Abstract. An experiment was carried out to determine the symbiotic effect of mycorrhiza on the yield and root characteristics of *Sorghum vulgare* under water stress. The experiment was carried out in a factorial test using a Randomized Complete Block Design (RCBD) in three replications. Treatments were conducted base on drought stress in four levels and mycorrhiza were applied in two ranges M_1 (inoculated by mycorrhiza) and M_0 (non-mycorrhiza). The Results showed that, the drought stress had significant influences on dry matter of shoot, length of the root and percentage of the mycorrhiza colonization. It seemed that, the mycorrhiza had significantly increased the biomass of sorghum by influences on the root characteristics, such as: root length, colonization and root/shoot ratio.
Key Words: mycorrhiza, drought stress, *Sorghum vulgare*.

Introduction. It is well known that a considerable number of bacterial and fungal species possess and constitute some functional relationships with plants, and undoubtedly they are able to exert beneficially effects on plant growth (Vessey 2003). Considerably, there are significant evidences which express these beneficial microbial effects. These microbes or fungi can enhance the plant resistance to different kinds of environmental stress, e.g. water and nutrient deficiency or even contamination by heavy metals (Shen 1997).

It was reported by many authors that, the mycorrhizal colonization had results in the enhancement of root surface which can lead to an optimal nutrient absorbance; correlatively the extrametrical fungal hyphaes may extend into the soil for several centimeters and consequently lead to a large absorbance amount of nutrients for the host root (Khan et al 2000). Arbuscular Mycorrhizal Fungi (AMF) contributes to an enhancement in uptake of Phosphorous and micronutrients (Krishna & Bagyaraj 1991). Since AMF are able to grow beyond the depletion zones around the plant roots, they are able to increase the uptake of immobile nutrients such as P and also micronutrients (Hodge et al 2001). Mycorrhizal symbiosis can act as a connector of root and the surrounding soil microhabitats by linking the biotic and geochemical portions of the ecosystem (Toro et al 1997). Considerably, factors such as: condition of soil, interactions between roots and shoots, the related functional and signal aspects, turgor pressure, yield threshold will lead to a root growth and root elongation (Munns & Cramer 1996).

It was shown that, the presence of AMF causes the host plant to grow more efficiently through a series of complex communications under the biotic and abiotic stressful conditions, such as: drought (Subramanian & Charest 1997; Porcel et al 2003), salinity, heavy metal contamination (Rivera-Becerril et al 2002), suboptimal root zone temperature (Liu et al 2004), or even soil compaction (Miransari et al 2007). The extended network of AMF enables the fungi to increase the nutrient uptake in plants by improving the soil structure directly (Harrier 2001), or indirectly (Rillig & Mummey 2006). The isolation of AMF may differ in their ability to influence on the stability of soil aggregates (Piotrowski et al 2004; Enkhtuya & Vosatka 2005). AMF produces a glycoprotein called glomalin, which cause the AMF to from a stable structure of aggregates with the host plant (Wright & Upadhyaya 1996; Rillig 2004). Under the stress free conditions AMF are able to act synergistically and enhance the plant growth by a series of mechanisms such as: enhance the fungal germination and growth (Carpenter-Boggs et al 1995) or enhance the permeability cells of root, resulting an increase in water absorbtion and nutrient uptake (Artursson et al 2006).

Material and Method. The experiment was carried out in a factorial test by using a Randomized Complete Block Design (RCBD) in three replications. The soil for the plots were chosen from a normal agricultural field from the depth between 0-20 cm and consequently were sterilized under pressure of 15 psi at 121.5 °C for 2 hours to be cleaned from other microorganisms. The seeds were inculcated by *Glomus intraradices,* an Arbuscular Mycorrhizal Fungus.

Consequently, treatments were conducted base on drought stress in four levels: I_1- re-irrigation when 75% of plant-available water was existed. I_2- re-irrigation when 55% of plant-available water was existed. I_3- re-irrigation when 35% of plant-available water was existed. I_4- re-irrigation when 15% of plant available water was existed.
To conduct the treatments for water stress, first the Bulk Density (Pb) were determined, and under the category of Field Capacity (FC) and Permanent Wilt Point (PWP) the "Available" Soil Water (ASW) were analyzed by following formula ASW= FC-PWP. Notably, the available water at FC point was supposed as 100% and the other treatments calculated base on it.

Finally, the dry shoot matter, root length (RL), the ratio of shoot to root, root length colonization (RLC), percentage of the root colonization (PRC) and response of treatments to mycrorhiza inculcation (RTM) were measured/calculated. To measure the root length, colonization root length and their percentages the following formulae were used. For the root length measurements:
RL=11/14* ND where,
N: number of roots from the horizontal and vertical lines;
D: the sideward length of square.

The response of treatments to mycorrhiza inculcation was measured by following formula: RTM= Mycorrhiza dry matter - Non-mycorrhiza dry matter / Non-mycorrhiza dry matter *100.

Finally, the obtained data were analyzed using a SAS software.

Results and Discussion. The analyses of variance among the treatments are presented in Table 1 and 2; according to them, mycorrhiza had significant influences on shoot's dry weight and correlatively, the highest dry weight was achieved by I_3 treatment (37.75 g) even though there was not any significant difference between the other treatments (Table 3). The analysis of variance also showed that mycorrhiza and drought stress had significant influences on root length (Table 1 and 2). The mean comparison showed that, the enhancement of drought stress had caused a decrease in root length. In the counter point, the root length had achieved the highest value in the treatments which had been inoculated by mycorrhiza and the root extension by mycorrhiza was evident in those treatments. Undoubtedly, the root extension helps the plant to be more connected with soil and use more nutrients which consequently will lead to biomass synthesis and growth. Considerably, the highest root length was achieved in I_1 treatment (8161.7 cm) and the lowest length was achieved in I_4 treatment (7071.7 cm). Meanwhile, the analysis of variance showed that, the individual influences of mycorrhiza and drought stress on root/shoot ratio is significant but the simultaneous interaction of drought stress and mycorrhiza on root/shoot ratio is not significant (Table 1 and 2). Also the mean comparison showed that the root/shoot ratios were increased significantly by increase of drought stress tension. But the root/shoot ratios had the highest value in inoculated treatments by mycorrhiza. It seems that, the mycorrhiza had supported the root of plant in drought stress condition and caused an increase in root/shoot ratio. Relatively, the highest amount of root/shoot ratio was achieved in I_4 (0.245) even though there was not any significant difference between I_4 and I_3 treatments.

Table 1

Analysis of variance for the effect of drought stress and mycorrhiza on dry matter shoot, RTM and root/shoot ratio

Treatments	df	Dry matter shoot (g)	RTM	Root/shoot (ratio)
Repeats	2	59.5**	0.0028*	0.00022*
Mycorrhiza	1	988.17**	1.431**	0.0048**
Drought stress	3	421.39**	0.079**	0.0025**
Drought stress*Mycorrhiza	3	448.3**	0.076**	0.00009ns
Error	14	5.4	0.0007	0.00003
CV	-	4.28	-	8.29

Ns,*, **: non significant, significant at the 5 and 1% probability levels, respectively.

Table 2

Analysis of variance for the effect of drought stress and mycorrhiza on root length (RL), root length colonization (RLC) and percentage of root colonization (PRC)

Treatments	df	RL	RLC	PRC
Repeats	2	6731ns	5047615ns	3ns
Mycorrhiza	1	2117069**	39140334*	21660**
Drought stress	3	1403080**	48984458ns	452.7**
Drought stress*Mycorrhiza	3	260853**	498945ns	451**
Error	14	3094	56759195	3.5
CV	-	3.79	-	-

Ns,*, **: non significant, significant at the 5 and 1% probability levels, respectively.

Our results also revealed that, the mycorrhizal inoculum had significantly increased the extent of AMF colonization for the root system.

It was reported that, the symbiotic mycorrhizal fungi such as Arbuscular Mycorrhizal Fungi (AMF) or Ectomycorrhizal Fungi (ECF) are ubiquitous component for the most ecosystems throughout of the world and they are a valuable key for the soil microbiota (Bethlenfalvay & Linderman 1992; Van der Heijden et al 1998). It was also reported that, the mycorrhizal symbiosis mobilizes and transports nutrients to the roots (Smith & Read 1997) and it is well known that AMF improved the nutrients uptake (especially nitrogen and phosphorus) by increasing the abilities of the host plants to explore a larger volume of soil than roots and to mobilize the phosphate from a greater surface area (Jakobsen et al 1992; Joner et al 2000).

Authors have also claimed that, mycorrhiza reduces the water stress (Augé 2001) and improves the soil aggregation in eroded soils (Caravaca et al 2002). Mycorrhizal fungi affect the diversity of plant communities (Van der Heijden et al 1998; Klironomos et al 2000; O'Connor et al 2002) and influence the relationships between plants (West 1996; Marler et al 1999; Van der Heijden et al 2003). Mycorrhizal plants also transfer more assimilates to the roots than non-mycorrhizal ones. These fungi mainly affect the results of carbon demand for the fungal symbiont which may assimilate 10% of the carbon which allocated to the roots at the higher respiration levels of mycorrhizal roots (Kucey & Paul 1982; Fitter 1991). Moreover, mycorrhizal fungi may alter the root exudation quantitatively and qualitatively (Leyval & Berthelin 1993), as they catabolise some of the root exudates and modify some of the root metabolic functions.

Table 3

Mean comparison for the effect of drought stress on root length, root/shoot and root dry weight

Treatment	Root length (cm)	Root/shoot (ratio)	Root dry weight (g)
I1	8161.7[a]	0.200[b]	36.533[a]
I2	7857[b]	0.208[b]	36.967[a]
I3	7393.5[c]	0.230[a]	37.75[a]
I4	7071.7[d]	0.245[a]	33[a]

Means followed by the similar letters are not significantly different (Duncan 5%)

Shoot growth is usually more affected than root growth in a water stress condition (Munns & Cramer 1996; Pardo et al 2000). But under the water stress condition nutrient absorbance will decrease when nutrients (especially Nitrogen uptake) reduce, consequently, less cytokinin will be produced in the roots and it will be sent to the shoots. Considerably, the lower amounts of cytokinin result in the reduction of cell division in the shoots while in the roots this may lead to neutralizing the suppressing effect of cytokinin on cell growth and cell development. Also transfer of more sucrose to the roots enhances root to growth under these conditions (Van der Werf & Nagel 1996).

Table 4

Mean comparison for the effect of mycorrhiza on root dry weight, root length and root/shoot

Treatment	Root length (cm)	Root/shoot	Shoot dry weight (g)
M0	6681.8[b]	0.2066[b]	31.758[b]
M1	8560.2[a]	0.23500[a]	42.36[a]

Means followed by the similar letters are not significantly different (Duncan 5%).

Conclusions. This study significantly indicated that, the colonization of the plant roots by mycorrhizal fungi will lead to a successful growth of *Sorghum vulgare*. The fungi can assist plants to exploit the soil nutrients and may help them to resist drought stress in the shoots. AMF may also contribute to the re-establishment of a general soil micro flora and considerably, in the sustainable agricultural system combination the appropriate amount of fertilizers under the water limited conditions will demonstrate a brilliant view in this area; correspondingly further studies are necessary to determine the optimum depth of required soil and in this area long-term field studies will help to define the necessary inputs and conditions for successful annual crop production. After this particular study, we may conclude that: AMF can decrease the stressful effects of soil drought on sorghum growth by enhancement the process of nutrient uptake; undoubtedly, this importance depends on the compatibility with other existed microorganisms in the soil.

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