Comparison of Effectiveness of Arbuscular Mycorrhiza Fungi (AMF) on *Vitis vinifera* under Low Irrigation Conditions

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**ABSTRACT**

**Background:** Grapevine is an important perennial crop worldwide, consumed as fresh or dried (raisins) fruit. Grapevines are exposed to a variety of abiotic stresses during their growth. Water shortage is one of the primary stressors and severely restricts the development of the grape industry. Arbuscular mycorrhizal fungi (AMF), a kind of beneficial soil microorganism, can create a symbiotic association with plant roots forming arbuscular mycorrhizas (AMs), which play a role in the regulation of plant growth.

**Methods:** This research was accomplished in order to investigate the effect of 4 species mycorrhizal fungi on grapevine ‘Asgari’ cultivar under water stress conditions. We use of 3 irrigation regime that consist: 100% (as control), 70 and 40 % of field capacity. As well as, mycorrhizal treatments include: non-use of mycorrhizal (NM) and use of mycorrhiza (M) (*Glomus mosseae*, *G. intraradices*, *G. etunicatum* and *G. vericiform*).

**Results:** The results indicated that shoot and root dry weight, pigments (total chlorophyll and carotenoids), relative water content (RWC), P, Mg and Ca under water limitation decreased but electrolyte leakage (EL), proline and total soluble sugars (TSS) increased in M plants was higher than NM plants. Generally, the use of mycorrhiza fungi in this experiment reduced the harmful effects of water stress. Our results shown that *G. vericiform* and *G. etunicatum* were better for symbiosis with ‘Asgari’ grapevine under water limitation.

**Key words:** Drought, *Glomus* spp, Grapevine, Nutrient, Osmolyte.

**INTRODUCTION**

Grapevine (*Vitis vinifera* L.) member of family vitaceae, is one of the most important perennial crop worldwide and its one of the most economically momentous temperate fruit trees (Krithika et al. 2015; Stupic et al. 2019; Bettoni et al. 2019), its fruits are processed into products such as wine and juice or used as fresh table grapes or raisins. In 2017, grapevines enveloped 7.53 million ha and produced 73.3 million tons of fruit worldwide (Bettoni et al. 2019; Zyprian et al. 2018). Grape cultivated under tropical and sub-tropical regions of the world and the capability for *V. vinifera* to tolerate inappropriate environmental conditions for superlative crops will partially be dependent on the functioning on its soil society (Holland et al. 2014; Kumar et al. 2015).

Drought stress, decreased crop quality and yield and also restrict the geographical range over which production of crop is viable (Thakur et al. 2010; Kumar et al. 2018). Abiotic stress such as drought, causes generate secondary stresses, including oxidative and osmotic stress, which have harmful effects on the plants and causing changes in the plants growth, development and metabolism (Kranner et al. 2010). Plant species to cope with bad environmental conditions have expand a number of physiological, biochemical and molecular mechanisms. (Chen et al. 2011). Drought stress inhibits the plants photosynthesis, causes changes of chlorophyll contents and components and damage to the photosynthetic system (Salekjali et al. 2012). Thus, it is obligatory to steer research for obtaining cultivars, which would be more tolerant to drought stress. Water limitation is one of the adverse environmental factors that can extremely extent crops dispensation in the whole world (Cattivelli et al. 2008; Farooq et al. 2009; Fathi et al. 2017).

Arbuscular mycorrhizal fungi (MAF) is one of the most beneficial soil microorganisms in which most of the plants can establish a symbiosis with them. MAF help plants to improve the nutritional absorption and other functions such as osmotic regulation and photosynthesis that results in tolerance enhancement against biotic and abiotic stresses (Jothi et al. 2005; Hashem et al. 2015; Vimal et al. 2017). Nicolas et al. (2015) concluded that AMF inoculation technique can be recommended for sustainable viticulture in arid and semi-arid areas. Mycorrhizal formation has been associated with enhanced growth, elevate mineral uptake from soil and increased tolerance against drought conditions (Trouvelot et al. 2015; Bavaresco and Fogher, 1996). The mycorrhiza is fungi-plant roots bilateral coexistence. AMF could expand root absorbing surface, elevate stomatal conductivity, transpiration rate and RWC, as well as reduced
the leaf water potential and permanent wilting point (PWP) under stress condition and promote hydrological cycle in plants and induce a dynasty of defense responses mechanisms when experienced hardness (Ruiz-lozano et al. 1995; Li et al. 2002; Wu et al. 2009). Under water deficit plants associated with AMF show enhanced osmotic regulation and root hydraulic properties than non ones (Ruiz-lozano et al. 2012). The inoculation of pistacia vera with AMF enhanced drought tolerance of plants by promoting nutrient uptake (Bagheri et al. 2012). Zhang et al. (2016) reported that mycorrizal hyphae benefited soil water absorption and nutrient uptake in grassland plants also previous studies have shown that drought tolerance of plants could be improved by AMF (Lu et al. 2003). For instance, Zhang and He (2007) reported that AMF can modify the protective system and enhancement the drought resistance of Artemisia ordosica plants. Wu and Xia (2005) noticed that the ability of A. ordosica against drought stress was elevated by insemination with the AMF. Studies carried out by Yooyongwech et al. (2016) and Quiroga et al. (2017) showed that, when subjected to drought, mycorrhizal potato and maize plants had higher level of photosynthetic pigments than those not colonized by AMF. Thus, one of the most important strategies to use in novel viticulture under water limitation is the choice of the privileged adapted rootstock and best MAF for symbiosis.

The aim of this study was, to investigate the effects of different species of AM fungi on drought tolerance of one of the most important grape cultivars in Iran. In this experiment, the effect of AMF symbiosis on morpho-physiological and nutritional characteristics of ‘Asgari’ grape was investigated.

**Materials and Methods**

**Mycorrhizal inoculum and stress conditions**

Glomus mosseae, G. intraradices, G. etunicatum and G. versiforme were multiplied in a sterile potted soil cropped with Zea mays L. between June and October 2018. Inoculum of AMF was included of spores, hyphae and mycorrhizal root pieces of corn and it was used to grape cuttings of corn. In this experiment, ‘Asgari’ grapes were used and the mycorrhizal grape cuttings were treated with inoculum (non-mycorrhizal plants were not inoculated) and they cultivated at 10 L pots. Plants were grown for three months in an experimental greenhouse in Shahrekord, Iran (32°21’ N, 50°49’ E) with middle temperatures and relative humidity of 26°C and 42% respectively. Water treatments in three levels (100, 70 and 40% of field capacity - FC) were applied in three replications (two plants in each replication) in the basis of FC. The FC was determined by the gravimetric method according to Souza et al. (2000).

**Pigments, RLWC and Electrolyte Leakage**

Contents of pigments (chlorophyll and carotenoids) in these experiments were estimated matching to Lichtenthaler (1987) method. To determine relative leaf water content (RLWC) samples (100 mg) of fresh leaf weighed fresh weight (FW), then placed in distilled water and shaken for 4 h and samples were weighed [as total weight (TW)], after that samples were dried at 65°C for 48 h and weighed again [dry weight (DW)]. The RLWC was computed by following equation (1): (Gonzalezvillar, 2001)

\[
\text{RLWC} \% = \left(\frac{\text{FW} - \text{DW}}{\text{TW} - \text{DW}}\right) \times 100
\]

For Electrolyte leakage (EL) assay 15 freshly cut leaf discs (1 cm²) were rinsed 3 steps (2-3 minute) with double distillation water and after that floated on 10 mL of water. Subsequently the EL in the solution was calculated after 24 h at room temperature using a conductimeter (Crisón Instruments, S.A., Spain). Total conductivity was measured after keeping the samples in an oven (90 °C) for 2 h. Results were represented as % of total conductivity.

**TSS and Proline**

Total soluble sugar (TSS) was estimated through Irigoyen et al. (1992) method. Proline content estimated based on reflex with ninhydrin according to Bates et al. (1973). For this purpose, one solution of proline, ninhydrin acid and glacial acetic acid (1:1:1) was prepared and incubated at 100°C for 1 hour. Subsequently reaction was seized in an iced bath and the cromophore was extracted with 4 ml toluene and its absorbance at 520 nm was registered. Proline content was assessed with a standard curve and expressed as µg.g⁻¹ FW.

**Nutrient**

Dried samples of leaf and root were weighed singly and ground to transit a 40 mesh sifter. The leaf and root samples were dry-ashed at 500°C, in the following plant sample solved in 10 cc hydrogen chloride (HCl 2N) and made the volume to 100 cc with distilled water. Mg²⁺, Ca²⁺ and Fe²⁺ concentrations were measured by atomic absorption spectrometry and K⁺ content was estimated by flame photometry. The content of leaf and root P in the digest was obtained by the ammonium molybdate blue method using spectrophotometry (Chapman et al. 1982).

**Root sampling and assessment of MAF colonization**

The experiment was finished 40 days after treatments beginning and separating shoots from roots. After washing the roots with tap water the roots of 2 plants in each pot was mixed and cut into 1 cm size pieces. Mycorrhizal symbiosis evaluation were prepared via Phillips and Haymann (1970) method. Roots sample were boiled for 1 h in 15 % KOH and then washed with water. Staining of roots pieces was accomplished in 0.05 % trypan blue and 15 min autoclave. Thereafter, roots pieces were kept in lacto glycerol. Finally, colonization of mycorrhizal was measured using 50 root segments of each sample by compound microscope (Giovannetti and Mosse, 1980).

**Statistical analysis**

Data were evaluated by Two-way analysis of variance (ANOVA) with SPSS 25.0.0 (Inc., Chicago, IL, USA). When treatments interactions were significant (P ≤ 0.05), means
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were separated using Duncan’s multiple range test at $P \leq 0.05$. Principal component analysis (PCA) was evaluated by R version 3.5.2.

### RESULTS AND DISCUSSION

According to the results, root dry weight (DW) in plants treated with mycorrhizae (M) plants was significantly higher than NM plants under both stress conditions. As well as, shoot/root in *G. etunicatum* and *G. mosseae* was lower than another fungi (Table 1). Under drought stress, biomass (root and shoot DW) decreased and the lowest shoot and root DW and shoot/root ratio was in MAD 60 (Table 1).

The chlorophyll a, b and total chlorophyll decreased under water limitation and the lowest level of chlorophyll a, b and total were observed at MAD 60 (FC 40). Reductions in chlorophyll a, b and total chlorophyll content in Mycorrhiza plants were lower than those without Mycorrhiza and the highest chlorophyll a, b and total chlorophyll were 2.71, 0.94 and 3.65 mg.g$^{-1}$ DW respectively in *G. versiforme*. carotenoids increased under drought stress. Higher level of Car was observed in the *G. etunucatum* (Fig 1).

Under drought stress electrolyte leakage (EL) increased but in M plants was lower than NM plants. More EL was observed on MAD 60 (90.7%). The effect of low irrigation and mycorrhiza species on RWC was significant. RWC decreased 31.2% under low irrigation conditions on compare with control but RWC was higher in M plants than NM plants, although there was no significant difference between control and *G. mosseae* (Fig 2).

Reducing irrigation (MAD 60) increased the TSS content of shoot and root, which was significantly different with control (MAD 0). An increase in TSS in the shoot and root M plants, less than NM plants. Most TSS of shoot and root on NM plants in MAD 60 was with an average of 39.22 and 46.12 mg.g$^{-1}$ DW respectively. The results indicated that interaction of treatments on shoot and root proline content was significant. No significant difference was observed between treatments in MAD 0 on shoot proline. In MAD 30 and MAD 60, the amount of shoots proline increased and the lowest shoot proline content was observed in *G. versiform* and *G. etunicatum*. Under drought stress roots proline increased and proline content on NM plants was more than M plants. The highest root and shoot proline (32.2 and 66.5 μg.g$^{-1}$, respectively) on NM plants was observed in MAD 60 (Fig 3).

Results comparison of shoot and root nutrient are shown in Table 2. The effect of drought and mycorrhiza on Ca$^{2+}$, K$^+$, Mg$^{2+}$ and P in shoot and root was significant. The nutrient content in root and shoot was significantly higher under irrigated conditions and inoculated with mycorrhizae. Generally, the Ca$^{2+}$, K$^+$, Mg$^{2+}$ and P content of shoots and

### Table 1: Root and shoot dry weight (g) of grapevine 'Asgari' symbiosis with mycorrhizal fungi (*G. mosseae, G. versiform, G. etunicatum, G. intraradices*) under different levels of dryness conditions (MAD).

| Shoot DW (g) | Root DW (g) | Shoot/Root |
|-------------|-------------|------------|
| Non Mycorrhiza | 6.33 b | 18.40 d | 0.35 a |
| *G. mosseae* | 7.48 a | 27.61 b | 0.28 bc |
| *G. versiforme* | 7.61 a | 24.39 c | 0.32 ab |
| *G. etunicatum* | 8.33 a | 32.21 a | 0.26 c |
| *G. intraradices* | 8.12 a | 22.42 c | 0.36 a |
| MAD0 | 8.80 a | 26.25 a | 0.35 a |
| MAD30 | 7.99 b | 26.53 a | 0.31 ab |
| MAD60 | 5.93 c | 22.24 b | 0.28 b |
| Non Mycorrhiza | 7.84 b-d | 23.18 c-e | 0.34 b-e |
| MAD0 | 6.90 b-e | 20.07 e | 0.34 b-d |
| MAD30 | 4.25 f | 11.95 f | 0.36 bc |
| *G. mosseae* | 8.72 a-c | 34.27 a | 0.26 d-f |
| MAD0 | 7.18 b-e | 29.35 ab | 0.24 ef |
| MAD30 | 6.53 de | 19.22 e | 0.34 b-e |
| *G. versiforme* | 8.48 a-d | 20.02 e | 0.42 ab |
| MAD0 | 7.48 b-d | 27.26 bc | 0.27 c-f |
| MAD30 | 6.87 c-e | 25.90 b-d | 0.27 d-f |
| MAD60 | 9.94 a | 30.21 ab | 0.33 b-e |
| *G. etunicatum* | 8.26 a-d | 33.64 a | 0.25 d-f |
| MAD0 | 6.80 c-e | 32.79 a | 0.21 f |
| MAD30 | 10.13 a | 22.31 c-e | 0.46 a |
| MAD60 | 5.20 ef | 21.36 de | 0.25 ef |

Comparison means by Duncan’s test ($P < 0.05$) were shown for the significant main effect. Different letters indicate significant differences among data within the same factor. The vertical bars indicate the standard error.
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**Table 2.** Comparison of mean of root and shoot nutrient (Ca²⁺, K⁺, Mg²⁺ and P mg.g⁻¹ dw) of grapevine ‘Asgari’ symbiosis with mycorrhizal fungi (*G. mosseae, G. verciform, G. etunicatum, G. intraradices*) under different levels of dryness conditions (MAD).

| Root          | Ca   | K    | Mg   | P    | Shoot          | Ca   | K    | Mg   | P    |
|---------------|------|------|------|------|----------------|------|------|------|------|
| **Non Mycorrhiza** |      |      |      |      | **Non Mycorrhiza** |      |      |      |      |
| MAD0          | 10.18 b-d | 3.13 a-d | 2.25 de | 1.10 e-h | MAD0 | 10.51 c | 4.49 c | 2.34 c-e | 1.41 c-e |
| MAD30         | 9.90 c-d | 2.28 cd | 2.67 a-d | 1.29 d-g | MAD30 | 10.55 c | 4.67 c | 2.31 d-e | 1.07 e-g |
| MAD60         | 8.13 e | 2.09 d | 1.74 f | 0.77 h | MAD60  | 9.78 d | 2.74 d | 1.81 e | 0.83 g |
| **G. mosseae** |      |      |      |      | **G. mosseae** |      |      |      |      |
| MAD0          | 10.66 ab | 2.99 a-d | 2.77a-c | 1.67 b-d | MAD0  | 11.09 bc | 10.70 a | 2.79 a-d | 2.03 ab |
| MAD30         | 10.31 bc | 2.52 b-d | 3.00 a  | 0.97 gh | MAD30 | 10.96 bc | 4.28 a | 2.78 a-d | 0.98 fg |
| MAD60         | 10.95 a | 3.52 ab | 2.69 a-d | 1.77 a-c | MAD60 | 11.93 a | 6.96 b | 3.11 ab | 2.34 a |
| **G. verciforme** |      |      |      |      | **G. verciforme** |      |      |      |      |
| MAD0          | 10.21 b-d | 2.85 b-d | 2.79 ab | 1.51 c-f | MAD0  | 10.86 bc | 4.51 c | 2.91 a-d | 1.71 bc |
| MAD30         | 9.92 cd | 2.56 b-d | 2.40 b-e | 1.30 d-g | MAD30 | 10.57 c | 3.99 cd | 2.54 b-e | 1.37 c-f |
| MAD60         | 9.65 d | 2.89 b-d | 2.84 ab | 1.62 b-d | MAD60 | 11.3 b | 4.48 c | 2.89 a-d | 2.35 a |
| **G. etunicatum** |      |      |      |      | **G. etunicatum** |      |      |      |      |
| MAD0          | 10.26 bc | 2.95 b-d | 2.76 a-c | 1.28 d-g | MAD0  | 10.58 c | 4.13 cd | 2.71 a-d | 1.48 cd |
| MAD30         | 9.96 cd | 3.30 a-c | 2.18 ef | 1.07 f-h | MAD30 | 10.61 c | 4.03 cd | 2.51 b-e | 1.18 d-g |
| MAD60         | 10.10 b-d | 2.99 a-d | 2.98 a | 2.02 ab | MAD60 | 10.75 bc | 4.59 c | 3.08 a-c | 1.61 c |
| **G. intraradices** |      |      |      |      | **G. intraradices** |      |      |      |      |
| MAD0          | 10.16 b-d | 2.44 b-d | 2.44 b-e | 1.54 c-e | MAD0  | 10.81 bc | 3.39 cd | 2.19 de | 1.39 c-e |
| MAD30         | 9.94 cd | 2.20 d | 2.33 c-e | 0.95 gh | MAD30 | 10.51 c | 3.29 cd | 2.36 b-e | 1.07 e-g |

Comparison means by Duncan’s test (P < 0.05) were shown for the significant main effect. Different letters indicate significant differences among data within the same factor. The vertical bars indicate the standard error.

**Fig 1:** Effect of different irrigation levels (MAD) and mycorrhiza (*G. mosseae, G. verciform, G. etunicatum, G. intraradices*) on the Chlorophyll a, b, total and Car of ‘Asgari’ grape.

Roots of plants that symbiosis with *G. versiform* was more than other mycorrhizae species. The quantity of P was higher in plants treated with mycorrhizae (M) over untreated plants (NM). The higher shoot P was found in MAD 0 in *G. verciform* (2.34 g.kg⁻¹) and *G. etunicatum* (2.35 g.kg⁻¹) fungus but the most root P was observed under MAD 0 and *G. mosseae* (2.23 g.kg⁻¹) fungi (Table 2). The shoot Fe²⁺ was influenced by the effect of treatments. Water limitation decreased shoot Fe²⁺ concentration and symbiosis plant with mycorrhiza had the more Fe²⁺ content compared to control (Fig 4).

Altogether, the results shown that the symbiosis rate of *G. etunicatum* with ‘Asgari’ roots was more than other species of fungi (Fig 6). Also, the symbiosis plants with *G.
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etunicatum were better than the other of the fungi in terms of shoot and root DW, chlorophyll and carotenoids, RWC and root Mg²⁺ and P content under drought stress conditions. Biomass was higher in M plants, which could be owing to effects of mycorrhizal symbiosis on P absorption and other minerals such as K⁺, Ca²⁺, Mg²⁺ (Abdel-Salam et al. 2018) furthermore in M plants, water uptake and RWC was improved. Biomass reductions under drought stress conditions has been reported in previous studies on almond (Fathi et al. 2017) and peach (Rieger et al. 2003) fruit trees. Drought condition may reduce cell division, leaf area and chlorophyll content and finally, decreased in fresh and dry weight (Nadeem et al. 2014).
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**Fig 4:** Effect of different irrigation levels on the basis of moisture content between field capacity and permanent wilting point (MAD) and mycorrhiza species (G. mosseae, G. verciform, G. etunicatum, G. intraradices) on the shoot Fe of ‘Asgari’ grape.

**Fig 5:** Principal component analysis (PCA) Biplot from characteristic of Leaf (L) and Root (R) in ‘Asgari’ grape symbiosis with mycorrhiza (G. mosseae, G. verciform, G. etunicatum, G. intraradices) under irrigation levels (MAD).

**Fig 6:** The effect of different irrigation levels on colonization percent of ‘Asgari’ grape.
Plants inoculated with mycorrhizae had significantly enhanced chlorophyll content in leaves than control. These results are in agreement with previous studies (Giri and Mukerji, 2004; Sannazzaro et al. 2004; Colla et al. 2008). M-mediated increased Mg$^{2+}$ and Fe$^{2+}$ uptake, which they are essential for biosynthesis of chlorophyll. In host plants, chlorophyll might be less degraded because the plants were in better conditions in terms of moisture and mineral nutrition. The contents of carotenoids significantly increased under water limitation, carotenoids content are correlated with the capacity of light-protecting mechanisms and they are good known for their antioxidant activity, inhibiting peroxidation of lips, fixing membranes and as well as serious role in the assembly of the light harvesting complex and in the radiationless scattering of surplus energy. (Demmig-Adams and Adama, 1996; Munne-Bosch and Alegre, 2000). Therefore, the results of this experiment determined that mycorrhizal plants provided stronger photoprotective system against drought condition compared with non-inoculated plants by make more leaf carotenoids concentration.

It is observed from the mean values of Figure (2) that there is a decrease in the average RWC of the plant subjected to water shortage as compared to controlled conditions. Significant differences in RWC were observed between the different treatments tried. The improvement of RWC in M plants might be due to an improvement of the water absorption by M root system (Ruiz-Lozano et al. 1995). Moreover, increased water transport could also be attributed to improvement in P nutrition as well as the higher content of water soluble compounds in plant tissues could be a reason for higher plants RWC (Ruiz-Lozano et al. 2000 and 2012; Bagheri et al. 2012). The results showed that due to low irrigation, EL increased on compare with control. Plant membranes are exposed to changes often associated with the increment in permeability and integrity loss under drought stress condition (Blókhina et al. 2003). In that's why, the capability of cell membranes to control the rate of ion movement in and out of cells is used as a damage test to a great range of tissues.

The proline content of plant shown in the Fig (3). The proline content of the plants increase from normal ratio when they are subjected to drought stress. Some experiment were conducted that alterations in osmolyte content were verified (Sirici et al. 2005; Silva et al. 2009; Rodrigues et al. 2010). Accumulation of proline and TSS (as compatible organic solute) in response to water deficit cause to memorize cell turgor and reduced water potential of plant. Hence, mechanisms of drought tolerance is adjusted by this factors. (Hasegawa et al. 2000; Silva et al. 2009; Farooq et al. 2009). The increases in amount of TSS may happen as a result of the Inhibition of growth and by the water deficit intensity arising from starch degradation (Pimentel, 1999). The accumulation of compatible organic solute in root may due to the translocation of photo assimilates from leaves to roots and/or reduction in growth (Pimentel, 1999).

Decreasing of mineral nutrition’s (Ca$^{2+}$, K$^{+}$, Mg$^{2+}$, P and Fe$^{2+}$) under drought stress may be due to reduced root growth, because root growth, mineral transfer and mineral solubility in soils has an inverse relationship with water deficit. Also water scarcity has a negative effect on the minerals absorption and their transfer from soil to plant (Tsabarducus et al. 2015). The results of our experiment showed that under MAD 30 and 60 condition, P, Mg$^{2+}$ and K$^{+}$ contents of shoot were reduced whilst these nutrients in roots and shoot of M are more than NM plants. AM formation is widely believed to protect host plants from the harmful effects of water stress. Because, AM raise the nutrient uptake via expanding the exploration of the soil hole place (Auge, 2004). AM hyphae adhere to soil components by glomalin (a special glycoprotein) and amend contact with the soil solution under drought stress and these hyphae Increase the availability of roots to smaller pore spaces (Davies, 1992; Auge, 2004; Wu et al. 2009). In this study, associated of AM increased shoot and root P content of grape under water stress and AM plants are much more efficient in P up taking than NM plants leading to recovery in plant growth (Fitter and Hay, 2002; Desnos, 2008). K$^{+}$ content in M plants was more than NM plants and the results illustrated the positive role of AM symbiosis in Ca$^{2+}$, Mg$^{2+}$ and shoot Fe$^{2+}$ uptake. It has been illustrated in previous study that under low micronutrients level conditions such as stress, uptake by AMF hyphae is increased (Liu et al. 2000).

The mycorrhiza impose the secretion of phosphatase enzymes for P hydrolysis, which accelerates organic P compounds’ hydrolysis, resulting in better plant productivity under P deficiency conditions (Rashid et al. 2016). Maycorrhiza symbiosis helps the plant to expand into the rhizosphere and reach unexplored soil areas, having the opportunity to uptake more water and minerals. Also, the MAF has the ability to produce more enzymes and organic acids to make minerals available and expedites hyphae growth, which elevates the root efficacy in minerals’ absorption from the soil (Owen et al. 2015; Rashid et al. 2016). Maximum root colonization was registered in plants inoculated with AM strains followed by G. etunicatum. These variety between funguses may relate to the genetically controlled physiological characters, which play an important role in the absorption of nutrients from the soil and also their transfer to the root (Schubert et al. 1990).

**Conclusion**

In general, AM formation enhanced water stress tolerance of grape ‘Asgari’ at least in part via the increased absorption of slowly diffusing mineral ions such as PO$^{4-}$ and Fe$^{3+}$ and prepare more osmotic regulation which can be associated with K$^{+}$ accumulation in host plants. Nevertheless, AMF-mediated improvement of both growth rate and drought tolerance in plants is not just a nutritional process and some other mechanisms are also involved. Also the results indicated that chlorophyll a, b, total, proline decrease in NM plants was more than the M plants. Generally, the use of mycorrhiza in this research reduced the damaging effects of drought stress on the physiological and nutrition characteristics of grapevine, which in between the G.
verciform and G. etunicatum were better than the G. mosseae and G. intraradices. Therefore the role of various species of AMF in plants is different and some of plants may respond better to certain types of fungi.

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