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PHOTOSYNTHESIS AND EMISSION RELATED CHARACTERISTICS OF GRAPE (AMOUNT OF CO_2, TRANSPIRATION RATE, RELATIVE WATER CONTENT, LEAF TEMPERATURE, PHOTOSYNTHESIS INDEX, AND CHLOROPHYLL INDEX OF FRUITS) UNDER DROUGHT STRESS CONDITIONS

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ABSTRACT

To determine effect of inoculated roots of seedless white currant grape with three species of Mycorrhizal fungi (*Glomus fasiculatu*, *Glomus intraradices*, and *Glomus mosseae*) on some characteristics including net photosynthesis, stomatal conductance, under-stomatal CO_2, photosynthesis rate, amount of chlorophyll, leaf temperature, and leaf's relative water content under drought stress conditions, an experiment was designed in a factorial based on randomized complete block design with four replications. The results indicated that an increase in drought stress led to a reduction in the factors including shoot growth, a number of leaves, leaf level, root dry weight, and shoot dry weight. In comparison with control treatments, inoculation with mycorrhiza fungi had a positive effect on the aforementioned traits so that fungal treatment had the highest effect on chlorophyll index in a leaf of *Glomus mosseae* fungi. *Glomus fasiculatum* fungi had the highest positive effect on the index of photosynthesis index. Two *Glomus intraradices* and *Glomus fasiculatum* funguses had the most positive effects on the reduction in transpiration rate and sub-stomatal CO_2. All three funguses were effective in decreasing leaf area temperature. There was not any significant difference between 25% and 50% irrigation levels under water stress conditions. There was not any difference in CO_2, relative water content and transpiration rate at irrigation levels of 50% and 70%.

1. INTRODUCTION

For cultivated horticultural fruit plants grown in Iran, grape is the first rank for cultivation area

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*Corresponding author (Mohammad Aslanpour) E-mail: Aslanpour.mohammad@gmail.com and ranked after pistachio and date palm economically [1]. A study [2] introduced the Near East Region as the early place for grape creation based on the plant geological and archaeological studies. Herbal archeological studies suggest that grape domestication has begun since the second half of the fourth millennium BC in two neighboring areas, Mezopotamia (southern Anatolia, Syria, northern Lebanon, Kurdistan, and western Iran) and south of Caspian Sea. Water scarcity is an important factor limits the function of fruit trees in arid and semi-arid areas [35, 37]. Functional assessment of fruit trees under stress conditions and application of beneficial soil microorganisms as biological fertilizers to reduce damages caused by environmental stresses are novel solutions in sustainable agriculture in arid and semi-arid regions to reduce pollutions and environmental degradation [3-4].

Inoculation of grapevine shrubs with mycorrhiza fungi is one of the substantial methods used to improve water and nutrients assimilation especially in arid regions and poor soils.

2. THEORETICAL LITERATURE

According to the latest information published by FAO, grape production and yield of Iran and the world was equal to 67.7 million tons in 2012. Among countries in the world, 16 countries produced more than one million ton grape in 2012; of these countries, China with 9.600 thousand tons is at the first place and produces 11.5% of world grape production.

2.1 BOTANICAL CHARACTERISTICS AND CLASSIFICATION OF GRAPEVINE

Grapevine is from the Ampelidaceae family called Saramantaceae or Vitaceae. This family belongs to the Rhamnales species, which is Dialypetalae belonged to the angiosperms from the Spermatophytes. Such species include shrubs with Knitted shoots and grows upward due to their ivies. These ivies are located in front of claw-shaped leaves using them to stick to the tree or wall moving upward. Ampelography is the field of identifying genre, species, and variety of plants, which belongs to grapevines [5]. The white seedless cultivar has larger cultivation area compared with the red seedless grape. The white cultivar is grown rapidly and its branch length reaches to 2.5m with bright brown color. End buds of this cultivar are closed, hairy and white. Leaves are not hairy and have a dark green color with bright yellow nervure.

2.2 DROUGHT STRESS

Drought is defined as environmental conditions in which, soil or air prevent from enough water uptake by the plant, which leads to loss of critical function and water in plant’s tissue [6]. Drought is a factor, which limits the production of agricultural products in the world leading to considerable damage to such produces. Average rainfall in Iran is lower than one-third of the world [7]. Reduced amount of water in the soil and lack of water replacement leads to a decline in water potential in roots as well as a similar reduction in plant’s water potential. Sever water stress reduces photosynthesis, disturbs physiological processes, decreases plant function and dries the plant. The main factor leading to water stress in plants includes increasing transpiration rate and lack of water uptake and or a combination of them. Transpiration is under the control of some factors such as structure and area of leaves, the pore size of stomata, number of stomata and other factors affecting water vapor gradient between plants and air [8]. Water deficit response depends on the plant genre and cultivar, drought stress duration, plant growth step and age, type of plant organ and cell, sub-cellular organs, and plant structure. Most of the excellent plants perform various mechanisms to avoid or tolerate water stress as well as some methods to increase water consumption efficiency. In addition to some mechanisms such as reduced leaf area, increased storage organs, water storage potential, declined stomata and stomatal conductance, such plants employ some osmotic mechanisms and water resources existing apoplast to protect metabolic activities [9]. Drought stress affects the morphological traits of the plant such as leaf area, branch growth and root expansion, plant pigments, fresh and dry weight of leaf and root, physiological traits such as leaf's water potential, stomatal resistance, relative water rate of leaf, photosynthesis activity, photosynthetic adsorption of CO_2, evaporation and Proline accumulation [10- 11].In addition, drought stress leads to a water loss of plant tissue and cells, food deficit and reduction in CO_2 adsorption due to closed stomata and plant starvation. In some studies, drought stress led to a reduction in fresh and dry weight of leaf and roots, leaf area, leaf water potential, and relative water amount of olive and grape leaf [10-11].

2.3 DROUGHT STRESS AND PHOTOSYNTHESIS

Stomata are closed in the plant under the water stress conditions, there will be a subsequent decline in CO_2 concentration in mesophyll tissue, which leads to disturbance in dark reactions of photosynthesis, and the products obtained from light reactions (ATP, NADPH) are not consumed. Under such conditions, NADP+ consumption for electron capture is reduced due to lack of ADPH oxidation; therefore, oxygen molecule acts as electron substitute receiver in electron transfer chain forming superoxide radical (O_2^-), hydrogen peroxide (H_2O_2) and hydroxyl radical (OH^-) [12]. Photosynthesis limiting factors under water stress conditions can be divided into two groups:

A-stomatal limiting factors, which leads to a reduction in CO_2 release into intercellular space owing to reduced stomatal conductance. B- non-stomatal limiting factors created by the direct effect of water shortage on biochemical processes [13]. The major difference between transpiration and stomatal conductance seen in moisture treatments may be related to the strategy of the plant in closing pores in order to prevent from water waste, to resist against drought and to use the limited water optimally [14]. When drought period begins, the plant maximizes transpiration and stomatal conductance but the continuity of drought period makes the plant to narrow its pores and finally close them. As the continued openness of stomata depends on the turgor of supportive cells that are a part of the lead structure, reduction in relative water content (RWC) can be named as the other reason for different stomatal conductance and transpiration among various moisture regimes. Stomatal control is the first reaction of the plant against water shortage under farming conditions so that stomata react to hormonal signs such as generated ABA with roots [15].

Non-stomatal limiting factors include biochemical factors of photosynthesis such as the amount of chlorophyll, RuBis CO rate, and activity, photosynthetic electron transfer, photophosphorylation and amount of metabolites. [8] examined a study on stomatal conductance of two grape cultivars named reported reduction in sub-stomatal CO_2 under drought stress conditions at the first step then reported a rise in this variable. The initial reduction in CO_2 was associated with closed stomata and the subsequent rise was related to non-consumption of CO_2 within the photosynthesis process. Therefore, not drought stress reduces stomatal conductance through internal mechanisms of leaf but also prevents from CO_2 processing. Reduction in chlorophyll rate and RuBis CO activity is a non-stomatal factor under drought stress conditions, which leads to a decline in photosynthesis. Drought conditions lead to a decrease in formation of new plastids and chlorophylls a and b as well as their ratio [16].

2.4 MYCORRHIZAL FUNGI

The term “mycorrhizal” was introduced by Frank in 1885; this term is composed of two words “Myco”, which means fungus and “Rhiza”, which means roots indicating symbiosis between the fungus and plant roots. In this system, the fungus forms the broad coverage of the filamentous called hyphae around the host plant's root. Many plants can form mycorrhizal system; 83% of Dicotyledon and 79% of Monocotyledon plants can develop a mycorrhizal system [17]. Colonization with Arbuscular Mycorrhizal fungi can affect the water relations of plants under the full irrigation or drought conditions. The water content of a plant highly depends on the water waste through transpiration, water uptake by roots and conducting water toward other organs and fungi can affect these factors as well as texture hydration and leaf physiology. Mycorrhizal plants have a higher rate of leaf transpiration and stomatal conductance in comparison with non-mycorrhizal plants [18]. The impact of mycorrhiza on stomatal conductance may vary based on water availability. Under full irrigation conditions, stomatal conductance of non-mycorrhizal plants is almost two times greater than mycorrhizal plants. Stomatal conductance was considerably reduced in non-mycorrhizal plants after exposing to drought. However, stomatal conductance of mycorrhizal plants was considerably increased when the drought period was ended. At this step, non-mycorrhizal plants always showed lower stomatal conductance compared with mycorrhizal plants [19]. Mycorrhizal plants can expand water use efficiency by increasing photosynthesis and producing more photosynthetic materials per used water unit; these plants use a lower amount of water per dry matter unit production leading to higher water use efficiency. Mycorrhizal plants show a high water use efficiency under drought conditions [20- 21]. Mycorrhizal plants may have the extra potential to absorb water from the root area. Fungal hyphae can reabsorb a large amount of water, which conducts water toward the plant. It is assumed that external mycorrhizal multi-hyphae species have a specific capacity to absorb water [22].

There are numerous evidences on the ability of plants to expand their photosynthesis rate in order to meet their symbiotic needs. This process can be done by increasing leaf area and CO_2 stabilization per weight unit of the leaf. Mycorrhizal plants can assimilate higher CO_2 level compared to non-mycorrhizal plants under drought conditions. Despite the larger amount of photosynthetic materials transferring into the roots in mycorrhizal plants, such transfer cannot affect the dry weight so that a part of extra photosynthesis is used by the mycorrhiza in mycorrhizal plants [23]. Computational estimated costs of mycorrhizal symbiotic carbon equal 4-20% of fixed carbon within photosynthesis. In addition to higher carbon use, Mycorrhizal plants have higher photosynthesis rate, which depends on the higher rate of this process at leaf area and larger leaf area of such plants [22].

2.5 MYCORRHIZAL FUNGI IN GRAPE

Nowadays, Vinifera grape species is cultivated in regions with enough rainfall within the rainfed form and due to its drought and limestone soil resistance [24]. However, severe drought stresses in some years reduce the function rate at sensitive phonological steps such as fruit formation time. On the other hand, plantation of one-year-old seedlings in these arid regions makes problem in initial years owing to water deficit and improper soil. In addition to the use of resistant and premature cultivars, resistant bases and water management (rainwater harvesting, limited irrigation, and regional irrigation or PRDI), rootstock of grapevine is infected with mycorrhiza fungus (Arbuscular Mycorrhizal fungi (AMF)) in order to develop gardens in arid and semi-arid regions [25]. [26] studied the effects of one-year Sauvignon Blanc cultivar's roots inoculated with Arbuscular mycorrhizal on the water relations and some physiological traits. They reported that mycorrhizal fungi inoculation could increase stomatal conductance, photosynthesis and vegetative growth of seedlings while this treatment had no effect on biomass and nutrients rate. Improved water relations led to improved photosynthesis in grapevines carrying mycorrhiza.

3. MATERIALS AND METHODS

3.1 EXPERIMENTAL MATERIALS, PLAN, AND TREATMENTS

This study was conducted to improve nutritional situation, soil fertility and growth of white seedless grape under drought stress conditions; in this case, effects of inoculated one-year grape seedlings with several mycorrhiza funguses was examined on the water and nutritional relations under low irrigation conditions in the pot compared with the control group (without inoculation). This study was done during two years (2013-2014) in the form of a factorial experiment in the randomized complete block design with four replications. The factors included inoculation with three mycorrhiza fungus species (*Glomus mosseae, G. fasciculatum*, and *G. intraradices*) and without inoculation (four levels), and irrigation at three levels (stress levels).The soil bed of the pot composed of wind sand and crop soil in equal amount. The white seedless grape cuttings were prepared then rooted in the wind sand using Mamarov method. Half of the seedlings were inoculated in the Arbuscular Mycorrhizal (AM) fungi suspension at the same bed and rest of them were used as the control samples.

3.2 PREPARATION OF MYCORRHIZAL PLANTS

Mycorrhiza fungus inoculums (spore, mycelium, mycorrhizal roots, and soil) were taken from the Turan Biotechnology Company of Shahrood and propagated on Sorghum roots. To produce mycorrhizal seedlings, woody white seedless grape were put on the rhizogenic antiseptic rootstock sand bed, which has been mixed with Mycorrhizal fungus inoculum based on the 15:1000 ratio then sampling was done at each week in order to make sure of root colonization. Staining the root with Trypan blue 0.5% and making sure of colonization, colonization percent of roots was determined at the final step. Rooted seedlings, which were inoculated with mycorrhiza fungus at next step (end of winter), were put in 20-liter plastic pots. The seedlings were pruned as twin buds in early spring. The seedlings were pruned as twin buds in early spring. After 20-cm vegetative growth and plantation of seedlings, drought stresses were imposed as follows: the usable water for the plant was calculated based on the weight percent of agricultural capacity and wilting point then this rate was expressed as weight vale by consideration of the pot soil weight. Accordingly, the obtained usable water and stress treatments were applied. Irrigation treatments included 35%, 55% and 75% of usable water (agricultural capacity), which were not applicable in 100% capacity due to the constant need for water. According to the surveys, the irrigation plan was implemented within 2 days, 4 days and 6 days. To determine the physiochemical situation of the soil composition used for plantation of rooted seedlings, the soil sample was sent to the laboratory. The obtained results are reported in Table 1.

Table 1: Results of pots' soil analysis

Row	Characteristic	Unit	Irrigation plan within			Optimal range
			2day	4day	6day	
1	Depth	cm	0-30	30-60	60-90	-
2	Electrical conduction ($EC*10^3$)	Ds/m	1.61	-	-	<2
3	Acidity (PH)	-	7.43	-	-	5.5-6.7
4	Saturation percent (SP)	-	34	-	-	40
5	Lime percent ($Caco_3$) (T.N.V)	%	9.4	-	-	<15
6	Organic carbon percent (O.C)	%	0.16	-	-	>2
7	Total nitrogen percent (T.N)	%	0.02	-	-	>0.2
8	Available phosphorous (P_{ava})	Mg/kg	2.5	-	-	>15
9	Available potassium (K_{ava})	Mg/kg	154	-	-	>350
10	Clay percent	%	14	-	-	20-30
11	Silt percent	%	14	-	-	30-40
12	Sand percent	%	72	-	-	30-40
13	Soil texture	-	Sa.L	-	-	Loam, clay loam
14	Copper (Cu)	-	1.23	-	-	-
15	Iron (Fe)	-	5.91	-	-	-
16	Manganese (Mn)	-	4.03	-	-	-
17	Zinc (Zn)	-	0.53	-	-	-

3.3 PHYSIOLOGICAL TRAITS

Leaf's RWC was measured at the end of the experiment period. Two fully developed leaves were cut from each experimental unit in order to prepare discs with 8mm in diameter from the leaves' sheaths (10-leaf disc from each experimental unit). The aforementioned discs were weighted using digital scale (with 0.001g accuracy) then they were put into Petri dishes with distilled water kept for 4 hours in the fridge (under 4°C) in darkness. Discs were exited from distilled water in order to remove the extra moisture of discs' area then were dried using two filter papers and the weight of their turgor was measured. After determining turgor weight, leaf discs were put into the oven under 70°C and their dry weight was calculated after 48 hours; finally, RWC was calculated using equation 1.

$$\text{Relative Water Content (RWC)} = \frac{fresh\ weight\ of\ leaf\ discs - dry\ weight\ of\ leaf\ discs}{turgor\ weight\ of\ leaf\ discs - dry\ weight\ of\ leaf\ discs} \qquad (1)$$

3.4 LEAF TEMPERATURE

Under water stress conditions, two pots were randomly selected from each experiment in order to measure leaf temperature in stress treatments and comparing them with control treatments (without stress). In this case, the temperature of four leaves (from the top and bottom parts of the shrub) in each pot was measured using an infrared thermometer (Model Hi 99550 Hana) from a 4cm distance with the time interval 13-15 hours. Besides the measurement of leaf temperature, the ambient air temperature was read and recorded.

3.4.1 LEAF AREA

To measure leaf area, four leaves were chosen in nodes 4-5 and 7-8 nodes from each treatment the leaves' area was measured using graph paper and average leaf area was determined in each treatment.

3.5 PHOTOSYNTHETIC PARAMETERS

3.5.1 MEASURING NET PHOTOSYNTHESIS, STOMATAL CONDUCTANCE, SUB STOMATAL CO_2, TRANSPIRATION RATE AND LEAF TEMPERATURE

To measure the aforementioned parameters by portable photosynthesis measurer (Model L.C.I software version10.1) made in the UK, the youngest mature leaf of each plant and leaf connecting to plant was selected for the experiment. The measurement was done for 10-13 hours in clear and sunny days. In measurement processes, the temperature was about 32°C, vapor pressure to 2.3kPa and CO_2 concentration to 430µmole.

To this end, a mature leaf was cut from the middle part of each plant then it was clamped for 20 seconds and traits of stomatal conductance, net photosynthesis index, sub stomatal CO_2 and transpiration rate were read.

3.5.2 STATISTICAL ANALYSIS OF DATA AND APPLIED SOFTWARE

Before data analysis, normal distribution of data was examined using the Kolmogorov-Smirnov test (K-S) through SPSS® Software. Variables with non-normal distribution were standardized using suitable conversions. SAS® software was employed for analysis of variance (ANOVA) and a comparison of the measured traits. Means were compared using Duncan's multi-domain test. Moreover, Excel® software was used to plot charts.

4. RESULTS AND DISCUSSION

4.1 ANOVA

Results of the effects of mycorrhizal fungus treatments and water stress on photosynthesis-related characteristics (Table 2). Photosynthesis-related characteristics include amount of CO_2, transpiration rate, relative water content, leaf temperature, photosynthesis index, and chlorophyll index)

Table 2: ANOVA of photosynthesis-related characteristics.

Change source	df	Mean square						
		Stomatal conductance	Sub stomatal CO_2	Transpiration rate	RWC	Leaf temperature	Net photosynthesis	Chlorophyll index
Fungus	3	0.119^{ns}	2037.076*	17.696**	54.078ns	117.231**	31.22*	4.373*
Irrigation	2	0.569^{ns}	922.521^{ns}	8.854**	276.122*	7.426**	1.480*	14.722*
Fungus × irrigation	6	0.106^{ns}	403.99^{ns}	2.360^{ns}	114.194^{*}	4.835**	1.491^{ns}	5.226^{ns}
Error	36	0.206	611.506	1.735	78.776	0.800	8.358	4.684^{ns}
Change percentage		27	9	25	10	2.8	18	11

ns: lack of significant difference
** and * indicate significant difference at 1% and 5% levels, respectively.

4.2 STOMATAL CO_2 RATE

ANOVA results showed that fungal treatment had a significant effect on CO_2 rate in white seedless grape at the level of 5% (Table 1). The highest amount of substomatal CO_2 was observed in grapevines inoculated with *Glomus intraradices* and *Glomus fasiculatum* funguses. Grapevines without mycorrhizal funguses (control treatment) had the lowest amount of sub stomatal CO_2 (Figure 1). The obtained results showed a positive effect of mycorrhizal fungi, particularly Glomus intraradices, which led to the highest sub stomatal CO_2 consumption and photosynthesis rate in comparison with control treatment. Water deficit is modified owing to the increase in water uptake, roots' hydraulic conductance, osmotic regulation, changing stomatal control, and cell wall elasticity by hyphae of AMF [27]. In fact, roots are replaced with hyphae of funguses and the developed hyphae can uptake the requiring amount of water from land, can prevent from stomata closeness, and can make CO_2 assimilation possible; this result is matched with the obtained result of the present paper.

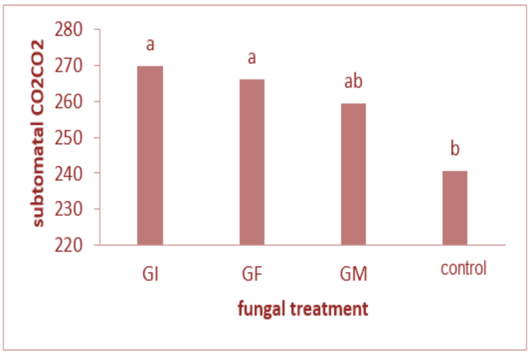

Figure 1: Comparing average sub stomatal CO_2 affected by fungus treatments.

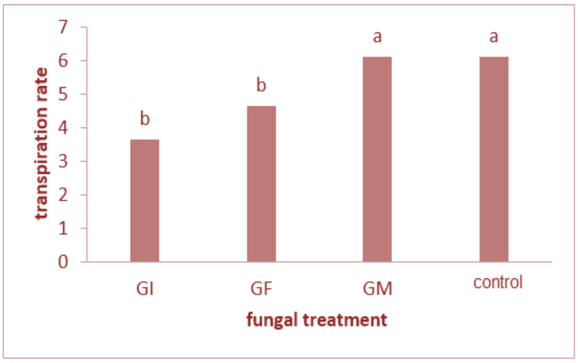

Figure 2: Comparing average transpiration rate affected by fungus treatments

4.3 TRANSPIRATION RATE

ANOVA results showed a significant effect of fungal and water treatments on transpiration rate in white seedless grape at a level of 1% (Table 1). The highest amount of transpiration rate and leaf area's temperature was observed in control treatment while the lowest rate was related to grapevines inoculated with Glomus intraradices fungi. In other words, Glomus intraradices fungi could reduce transpiration rate and prevent from drying and water loss in leaf (Figure 2).

The average rate of transpiration was significantly increased at the stress level of 25% in comparison with 50% and 75% levels (Figure 3).

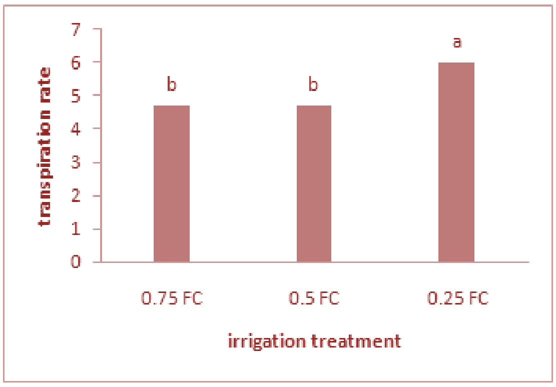

Figure 3: Comparing average transpiration rates affected by different irrigation levels

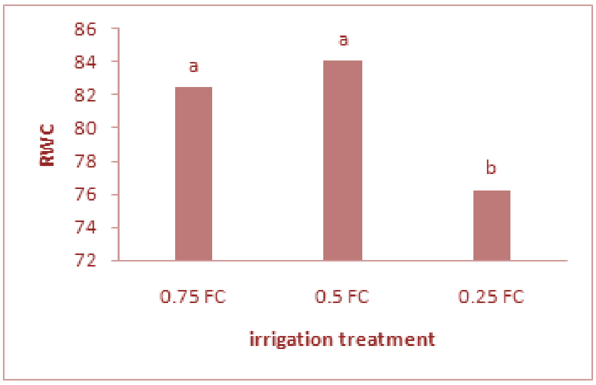

Figure 4: Comparing average RWC affected by different irrigation levels

A study [28] inoculated eight grapevines with mycorrhizal fungi and planted seedlings into the sandy soil with low amounts of phosphorous and organic materials in order to examine the effects of mycorrhiza fungi and low-level irrigation. Infection with mycorrhiza indicated positive effects on leaf water potential, stomatal conductance and photosynthesis rate under water stress conditions. The dry weight of mycorrhizal shrubs was greater than control treatment. The obtained results are in line with conducted studies.

4.4 RELATIVE WATER CONTENT (RWC)

ANOVA results showed a significant effect of water treatment on RWC of white seedless grape at a level of 5% (Table 1). RWC was reduced significantly at the stress level of 25% of farming moisture in comparison with 50 and 75% levels (Figure 4).

According to reports given by [16] and many researchers, RWC is an index, which is used to identify resistant and sensitive cultivars. Plant species protect the water content of their cells when dealing with drought [29]. Therefore, it can be explained that one of the significant mechanisms of resisting against drought used by grape is the protection of leaf's RWC. The shrubs, which can keep more water content in their leaves, are highly resistant against drought [30]. White seedless grape is a cultivar with medium cuticle thickness in leaves and studies show that this is not a drought-resists cultivar but can keep RWC of leaves at a high level under drought stress conditions and tolerate such conditions it is inoculated with mycorrhiza funguses. Figure 4 illustrates the lack of difference between 50 and 75% levels of farming capacity irrigation indicating a positive effect of mycorrhiza funguses and drought resistance. [28] inoculated eight grapevines with mycorrhizal fungi in order to examine the effects of mycorrhiza fungi and low-level irrigation. The obtained results showed that mycorrhizal infection increased leaf's water potential under the water stress conditions. The above-mentioned results are in line with previous works.

4.5 LEAF TEMPERATURE

ANOVA results showed a significant effect of fungal and water treatments on leaf temperature in white seedless grape at a level of 1% (Table 1). Figure 5 shows mutual effects and different water stress levels on leaf temperature. Leaf temperature is considerably affected by the stress and fungi so that the highest leaf temperature was seen at stress levels of control treatment compared with fungal treatments and the lowest leaf temperature obtained in 75% treatment with Glomusintraradices showed a significant difference between funguses. There was not any significant difference between control and *Glomus intraradices* fungi treatments at 25% and 50% levels, while there was a significant difference between treatments with *Glomus intraradices* and *Glomus fasiculatumin* terms of leaf area temperature. The highest rate of leaf area temperature was observed in grapevines inoculated with fungi at 25% level while the lowest rate was related to the level of 75%.

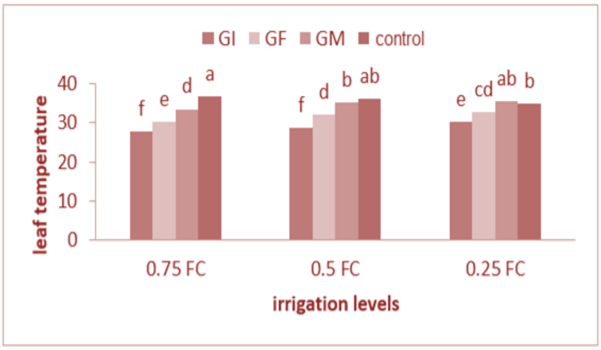

Figure 5: Comparing average leaf temperature affected by fungal treatments and different irrigation levels.

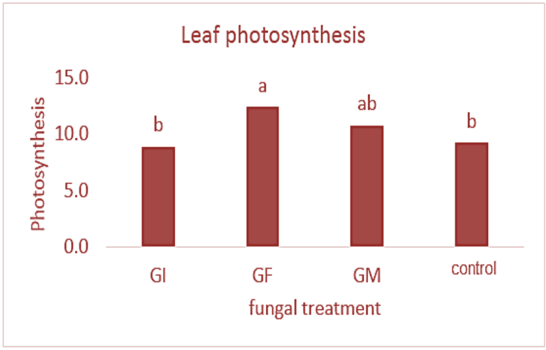

Figure 6: Comparing average rates of leaf photosynthesis affected by fungal treatments.

Leaf temperature is a new method used to estimate the stress rate of products [31]. Drought stress leads to the higher release of Abscisic Acid hormone, which reduces stomatal conductance and closes pores preventing from water loss of the plant. Long stress is reduced by the high-stress rate of leaves' growth; therefore, the reduced size of leaf leads to a decline in leaf area. The closed stomata and subsequent reduction in transpiration through leaf area make the potential for the plant to keep water. Under stress conditions, closed stomata lead to transpiration reduction and therefore increase in leaf temperature, which imposes thermal stress on the plant and stops plant growth. In fact, although transpiration reduction leads to leaf RWC protection, it may have two negative impacts on the plant, which include a decline in photosynthesis and increase in thermal stress risk. Increasing water stress levels led to a rise in leaf temperature in this research; this result was matched with experimental results related to grape obtained by [32] and [33]. Inoculated seedlings with Glomus intraradices can close stomata and increase leaf temperature by improving water uptake and keeping a higher level of RWC compared with other treatments; this showed the poor effect of stress on these seedlings.

4.6 PHOTOSYNTHESIS RATE

ANOVA results showed a significant effect of fungal and water treatments on photosynthesis rate in white seedless grape at a level of 5% (Table 2). The highest photosynthesis rate was observed in Glomus fasiculatum fungi. There was not any significant difference between photosynthesis rates in control treatment and treatments with Glomus mosseae and Glomusintraradices and there was not any significant difference between other funguses (Figure 6).

A study [34] found an increase in photosynthesis rate and water consumption yield in a symbiotic herbaceous plant with mycorrhiza and reduction in transpiration and evaporation rates; moreover, mycorrhizal plants can increase photosynthesis rate, reduce evaporation and transpiration, and decrease proline concentration in their tissues under salinity stress conditions. They expressed that mycorrhiza can expand the net photosynthesis rate in host plant by increasing phosphorous concentration. According to an experiment, inoculation of clover with mycorrhizal funguses increases leaf area, which leads to rising in chlorophyll rate and net photosynthesis rate during the plant growth period. The results of this study are in line with conducted studies in this field.

4.7 CHLOROPHYLL INDEX

ANOVA results showed a significant effect of fungal and water treatments on chlorophyll index in white seedless grape at levels of 1% and 5%, respectively (Table 2). The highest chlorophyll index was observed in *Glomus mosseae* fungi, which was significantly greater than control treatment; while there was not any significant difference between funguses (Figure 7).

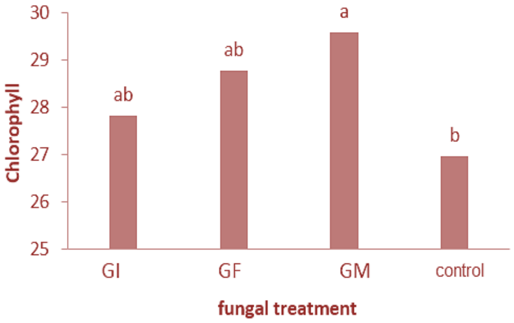

Figure 7: Comparing average amounts of chlorophyll affected by fungal treatments

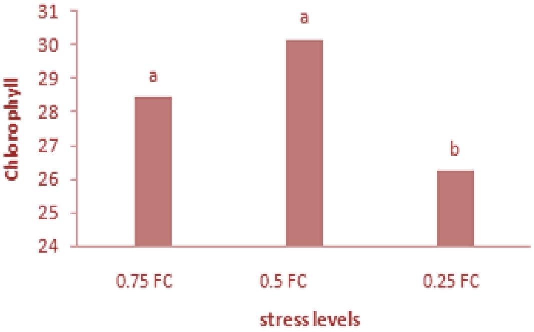

Figure 8: Comparing average amounts of chlorophyll affected by different water stress levels.

A report [12], chlorophyll content in Tangerine seedlings inoculated with fungi under irrigation conditions was 23% greater than seedlings without fungal treatment. In general, improved nutritional and environmental conditions can improve plant ability to produce chlorophyll in leaves and higher energy generation, which influences on chlorophyll content. The increased amount of chlorophyll under the effect of mycorrhizal inoculation may depend on the plant's phosphorous uptake from the soil [35-39].

According to a study on the plantation of Pinot Blanc grape on three sensitive, semi-sensitive and lime soil-resistant and inoculation of rootstocks with mycorrhiza fungi, iron amount and chlorophyll concentration were increased in leaves of seedlings inoculated with mycorrhiza [24]. This result is matched with the previous works.

Stress conditions affect the chlorophyll content so that a rise in drought rate lead to a decline in leaf chlorophyll content and the minimum value measured by Chlorophyllo meter device under the drought stress conditions obtained to 25% of water requirements. The leaves are smaller and thicker with dark green color under water stress conditions. There might be an error in measuring chlorophyll content by this device, which works based on the color (Figure 8).

5. CONCLUSION

The photosynthetic performance reduces severely in drought conditions, shading alleviated the drought impact. So, in this work, the effect of water deficit investigated under high or low intensity on the photosynthetic performance of grape plants. The dried leaf tissues not only disturb chlorophyll creation but also may degrade the existing chlorophyll. Drought may break chloroplasts and reduce chlorophyll content. Drought conditions lead to a decline in new plastids formation, chlorophyll types a, b as well as a change in the chlorophyll a to chlorophyll b ratio. Photosynthesis durability and chlorophyll maintenance of leaf are some of the physiological characteristics, which indicate drought resistance under stress conditions. This research reported a reduction in leaf chlorophyll content in grape cultivars due to lack of soil moisture, which is not in line with the result of the present paper.

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