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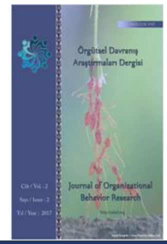

INVESTIGATING THE EFFECT OF MYCORRHIZA AND ZINC SPRAYING ON AGRONOMIC AND MORPHOLOGICAL TRAITS OF SORGHUM BICOLOR (L.) UNDER DEFICIT IRRIGATION CONDITIONS

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ABSTRACT

Water deficiency, especially in arid and semi-arid areas, is one of the most important reasons that limits production. The currentresearch was done to investigate the effect of Mycorrhiza (Mossea variety) and zinc spraying on agronomic and morphological traits of grain sorghum bicolor (L.) (Payam variety) under low irrigation conditions. It was conducted at the research farm of the Faculty of Agriculture, Islamic Azad University, Varamin,Pishvabranch. This research was conducted by means of a split factorial in a randomized complete block design with three replications. The main factors different levels of irrigation on three levels of total furrow irrigation (control treatment),fixed alternate irrigation and rotational alternate irrigation. Secondary factors of mycorrhizaat two levels include Mycorrhiza application and lack of mycorrhiza application and zinc spraying are mentioned in three levels of zinc sulfate spraying, zinc chelate spraying and spraying with distilled water. The studied characteristics include plant height, number of panicles, number of grains per panicle, yield components such as grain yield, 1000-grain weight, chlorophyll content, protein content, leaf relative water content, biological yield ,and proline. The results of agronomic and physiological traits disclosed that there was a significant difference regarding the main interaction effect between these traits and irrigation treatments, mycorrhiza application and zinc spray at 1 and 5% levels.And there was no significant difference in line with interaction effect of irrigation and mycorrhiza treatment with the number of grains per panicle and biological yield at 5% and 1000-grain weight at 1% level. Also, the triplicate interactions of irrigation, Mycorrhiza,and zinc with biological yield were significant at 5% level. Using Mycorrhiza in low irrigation conditions has led to a growth in the yield and water absorption of the plant which is economical.

Keywords: *Sorghum, Deficit irrigation, Mycorrhiza, Spraying, Zinc.*

INTRODUCTION

In terms of nutritional importance, Sorghum bicolor L. Moench is the world's fifth most important cereal after wheat, corn, rice, and barley (Cakmak, 1998). Sorghum is a one-year plant belonging to the cereals family (Gramineae), and its scientific name is Sorghum bicolor. The water requirement of this plant is at least 500 mm of rainfall during the growing season.

deficit irrigation is a deliberate and wise use of less water, to increase production in the covered lands, in other words, it can be indicated that deficit irrigation means more and better use of water volume unit.

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One of the main microorganisms in the root is Vesicular-Arbuscular Mycorrhiza (VAM). These fungi, by means of providing a synergy with crops, provide many benefits to their host. Increase in the absorption of water and nutrients in the host plant and as a result increasing the growth and resistance to drought stress, increasing resistance to pathogens, production of plant hormones, and improving soil structure through facilitating the formation of aggregates are among the advantages that the host plant will benefit from this coexistence (Pinior et al, 2005; Bhoopander, 2017).

The bean plants coexisting with mycorrhiza had a higher percentage of chlorophyll compared with non-Mycorrhiza plants (Thakur and Panwar, 2003).

The role of low-consumption elements in plants and some agricultural products include increasing production per unit area, and improving the quality of enrichment agricultural products. Ekiz et al. (2008) reported that zinc nutrition in plants is one of the major problems in arid and semi-arid areas. They also indicated that zinc shortage occurs in plants in arid and semi-arid areas soils, especially surface soils, which usually have water shortages; consequently, plants mineral nutrition is still one of the most significant determinants of the final production of plants (Streeter et al., 1984). Zn applicationon corn leads to increase in the total carbohydrate content of starch and protein of corn grain and augmented with increasing carbohydrate, grain weight, grain number and grain yield (Ekiz et al., 2008). In the soils with a different texture, the plant performance response to zinc is different. Studies have revealed that with the obliteration of the surface soil structure, due to the multiplicity of agricultural operations (tillage), zinc insufficiency increases in most of the products (Westfall et al, 2005). Westfall et al, 2005 have indicated that zinc deficiency can be seen in calcareous soils and land with continuous cropping, low drainage, sandy soils, and also the soils with high levels of phosphorus and silica. low-consumption nutritional elements are needed in relatively low concentrations in plant tissues that their lower demand of plants to the mentioned elements might be related to their participation in enzymatic reactions Ekiz *et al.* (2008). Microelements play important and intricate roles in plant nutrition and crop production (Ekiz *et al.* 2008).

The objective of this study was to investigate the morphological and agronomic traits of sorghum plant due to coexistence with Mycorrhiza fungus and zinc spraying under deficit irrigation conditions.

MATERIALS AND METHODS

This experiment was conducted to investigate the effect of mycorrhiza (Mossea strain) and zinc spray under deficit irrigation conditions on agronomic and morphological traits of sorghum (Payam variety) in Varamin province at the Agricultural Research College of Islamic Azad University of Varamin, Pishva branch. The current study was doneby means of split factorial in a randomized complete block design with three replications. The main factor in this research is irrigation with three irrigation levels of total furrow irrigation (I_1) fixed alternate irrigation (I_2) and rotational alternate irrigation (I_3). The subsidiary element includes two factors of mycorrhiza and zinc spray as M_1: lack of Mycorrhiza fertilizer application, M_2: grain inoculation with mycorrhiza fungus, Zn_1: zinc sulfate spraying, Zn_2: spraying with zinc chelate, Zn_3: spraying with distilled water. Before planting, the grains were inoculated with mycorrhiza and spraying was done from the 8-leaf stage, in three stages, every fifteen days. The distance between treatments was 120 cm and each replication consisted of 18 treatments. Each treatment consisted of 5 planting rows with a length of 5 m. The distance of the stacks from each other was 60 cm and the distance between the two plants on each line was 15 cm, and the first and fifth rows were considered as marginal effects. During the growth period, the yield components were calculated based on the average. The totalamount of chlorophyll in the field was measured by chlorophyll meter (SPAD502) in leaves. Grain yield was calculated in each sub terrace per ton/ hectare. Biological function is obtained from total dry weight of stem, leaf, and grain per ton/hectare, also the relative water content of the leaves was also measured. The harvest index was also calculated by means of dividing economic yield on biological yield in each sub terrace.

The results were analyzed by SAS 9.4 software and grouping was done by Duncan's multiple-range test at the 5% level.

RESULTS AND DISCUSSION

Plant height

The results of the table of variance analysis disclosed that plant height under the effects of simple irrigation, mycorrhiza, and zinc application was significant at 1% level, but none of the interactions of experimental treatments had a significant statistical effect on the plant height trait (Table 1).

The plant height was affected by water stress so that its maximum value with the height of 99.42 cm was related to total furrowirrigation, and the lowest value with an average of 80.36 cm was related to rotational alternate irrigation (Table 2). Among the different levels of mycorrhiza application, the highest plant height was gained from treatment with mycorrhiza with an average of 93.76 cm, and the lowest amount with an average of 86.02 cm was related to no mycorrhiza application treatment (Table 2). Accordingly, drought stress and not getting water and nutrients to vegetative organs caused a significant decrease in plant height. The obtained results are consistent with the results of Saleem (2003). By increasing the absorption of water and nutrients Mycorrhiza has increased photosynthesis, which increased plant height. The positive effects of mycorrhiza on increasing the height in different plants have been shown to produce more assimilate and improve plant growth, and as a result, the plant height is compared with the lack of application. The obtained results are consistent with the results of Qiangsheng et al. (2006), which shows that the positive effects of mycorrhiza have been proven with regard to the increase in plant height.

The number of panicle per plant:

Based on the results of trait variance analysis, the number of panicle per plant was affected by different levels of irrigation at 1% statistical level and influenced by mycorrhiza and zinc application in the 5% statistical level but none of the double and triple interactions of the experimental treatments did not have a statistically significant difference in the number of panicle per plant (Table 1). By applying the water stress, the number of panicle per plant was affected, so that the maximum and minimum values with averages 1.87 and 1.51 averages, respectively, belonged to total furrow irrigation and rotational alternate irrigation treatments

(Table 2). The obtained result indicates that the Sorghum plant produces more panicle in normal irrigation conditions under a common irrigation condition, but it faces a 10-percent decrease in the number of panicle per plant in the rotational alternate irrigation. Among the different levels of mycorrhiza, the highest number of panicle per plant was obtained from mycorrhiza treatment, which was 1.74 (Table 2). The application of different levels of zinc also caused changes in the number of panicleper plant, so that the highest amount was obtained with a mean of 1.74% from zinc sulfate spraying, which did not have a significant statistical difference with zinc chelate spraying and they were in a statistical group. The lowest number of panicle per plant with a mean of1.58 belonged to distilled water spraying (Table 2).

The number of grains per panicle:

The results of variance analysis of traits indicated that the number of grains in panicle was affected by different levels of irrigation, mycorrhiza, and interaction of irrigation and mycorrhiza at 1% level and affected by the use of zinc at 5% statistical level, but other interactions of treatments did not have a significant difference in the number of grains per panicle trait (Table 1 and Figure 1). Based on the obtained results of the means comparison, the mean of the main effects of the number of grains in panicle traits was affected by different levels of water stress. The highest number of grains per cluster with an average of 1314.38 belonged to total furrow irrigation and the lowest number of grains per cluster with an average of 1158.88 belonged to rotational alternate irrigation treatment (Table 2). With the use of mycorrhiza, compared with lack of using it, the number of grains in the panicle had an increasing trend which was equal to 1254.96. The number of grains in panicle increased with zinc application so that the highest value was obtained with an average of 1243.61 with zinc chelate and the lowest number with the average of 1218.22 obtained from the distilled water spraying treatment (Table 2). The results of the irrigation and mycorrhiza interaction effects disclosed that the highest number of grains in a cluster with an average of 1321.78 was related to total furrow irrigation treatment and mycorrhiza application and the lowest number was related to the rotational alternate irrigation and lack of mycorrhiza application treatments with an average of 1137.67 (Figure 1). Among the other important traits, which are referred as functional components, is the trait of a number of grains per panicle which has an effective role in the formation of grain yield as the weight of 1000 grains, it. The obtained result of the experimental treatment on the number of grains in panicle was influenced by mycorrhiza application and it was disclosed that the mycorrhiza application caused a significant increase in grain size in a panicle. Brien (2007) reported corn in the stage of inflorescence formation is more sensitive to water stress. Water stress during growth stages causes smaller female inflorescences and fewer grain rows.

Marschner (1993) reported that the effect of zinc applicationin corn increased the total starch carbohydrate content and protein of the grainshave been increased and with increasing carbohydrate, grain weight, grain number and, consequently, grain yieldwere increased.

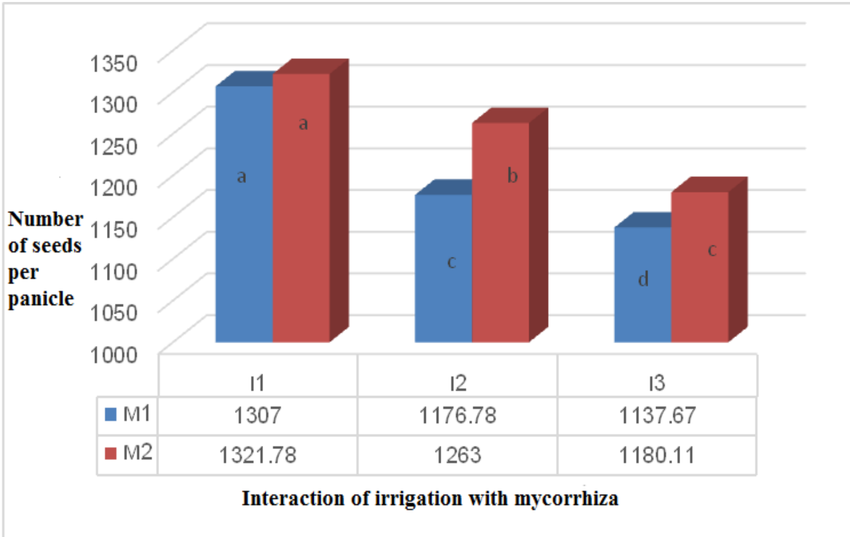

Figure 1: Investigating the interaction effect of different levels of irrigation and mycorrhiza

Grain yield

Based on the results of the traits variance table analysis it was observed that grain yield was significantly affected by different irrigation levels and Zn application, but mycorrhiza application and double and triple interactions of the experimental treatments had a statistically significant difference with grain yield (Table 1). Different levels of water stress caused changes in grain yield so that the highest grain yield with an average of 7.39 t/ha was obtained from total furrow irrigation and the lowest with an average of 7.14 t / ha was obtained from rotational alternate irrigation (Table 2). Water deficit stress reduces the weight of a thousand grains, which is due to the fact that water stress reduces the photosynthesis in the plant; therefore, it reduces the production of photosynthetic materials. Also, water deficit stress reduces the transfer of food from leaves to grains. It should also be noted that dryness causes the grains to grow quickly, as a result of this, it is effective in reducing the weight of the grains, because most plants while facing with water shortage, they reduce the amount of dry matter allocating to the aerial organ and the grain yield. The obtained results are consistent with the results of Samarbakhsh's (2009) research. Among the different levels of zinc, the highest grain yield was obtained with an average of 6.77 t/ha from zinc chelate spraying treatment, and its lowest value was related to distilled water treatment, which was 6.44 t/ha (Table 2). Thalooth et al. 2006 reported that spray application in a water stress condition has a positive effect, on growth, yield and plant components.

The weight of one thousand grains:

The results of variance analysis showed that 1000 grain weight was affected by simple effects of different levels of irrigation, mycorrhiza application, zinc application, and dual interaction of irrigation and mycorrhiza, but other interactions of experimental treatments did not have a significant difference on the weight of thousand grains (Table 1). Among the different levels of water stress, the highest 1000-grain weight was obtained from total furrow irrigation treatment, which was 37.77 g. Their lowest value with an average of 29.07 was related to rotational alternate the irrigation treatments that did not have any significant difference with fixed alternate irrigation and they were placed in a statistical class (Table 2). By means of mycorrhiza application, 1000-grain weight had a higher incremental rate than non-consuming treatments, so that the highest 1000-grain weight (32.48 grams) belonged to mycorrhiza application treatment (Table 2). Among the different levels of zinc application, the highest 1000 kernel weight with an average of 32.79gr belonged to zinc chelate spraying treatment, which did not have a statistically significant difference with zinc sulfate treatment, and they were placed in a statistical group. The lowest 1000-grain weight was obtained with a mean of 31.07 g from a distilled water solution (Table 2). The dual effects results of irrigation and mycorrhiza indicated that the highest 1000-weight weight was related to the total furrow irrigation treatment with mycorrhiza application with the average of 38.71 grams and the lowest value (28.96 gr) belonged to the rotational alternate irrigation treatment with mycorrhiza application (Fig. 2).

Hong & Ji-yun. 2007 report that drought stress leads to the grains weight reduction that is due to the effect on the current plant photosynthesis and the amount of material transferred to the grain. According to the obtained results, mycorrhiza fertilizer increases the grain weight by means of transferring the photosynthetic materials from leaves.

Researches on corn disclosed that there is a significant difference between the mycorrhiza application and lack of application treatmentsin line with grain yield and 1000-grain weight (Samarbakhsh *et al.*, 2009). In inoculated corn with Gintraradices mycorrhiza, compared to control treatment, grain yield, nitrogen, phosphorus, potassium, zinc, and manganese content of grains of these plants increased.

It has been reported that using roughly two to three kilograms of zinc sulfate ($ZnSo_4$) strips can easily eliminate zinc deficiency in sorghum (Lioyd and Howe, 2001). By means of zinc application in addition to yield increasing, zinc and protein concentrations will increase in the grains and shoots and will lead to better product quality.

Generally, 1000-grain weight is one of the yield components that are influenced by environmental and genetic factors, and it is the maximum plant requirement for water to increase the weight of 1000 grains in the stages of germination, flowering, and grain formation. Also in drought stress conditions, due to the high transpiration of the plant and evaporation from the soil surface, the relative water content of the leaves is reduced, as a result, photosynthesis will be limited, and the length of the grain filling period and successively the weight of 1000 grains decreases. Bukvic et al. 2003.

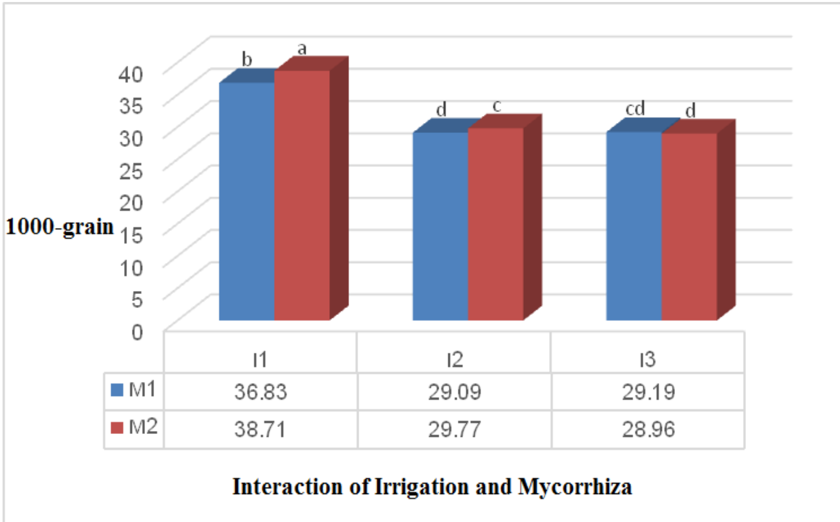

Figure 2: Investigating theinteraction of different levels of irrigation and mycorrhiza on 1000-grain weight

Table 1: Results of traits variance analysis

Sources of changes	S.O.V	Mean Square								
		df	Plant height	Number of panicles per plant	Number of grains per panicle	Grain yield	1000-grain weight	Leaf chlorophyll content	The relative water content of leaf	Biological function
Repeat	(R)	2	12.77^{ns}	0.001^{ns}	24.59.05^{ns}	278079.63^{ns}	0.79^{ns}	154.7^{ns}	59.05^{ns}	0.12^{ns}
Irrigation	(I)	2	1635.92**	0.57**	110.494.50**	8555646.30**	435.78**	11.57^{ns}	494.80**	29.54**
The main factor error	Error (a)	4	17.04	0.019	492.88	37976.85	0.16	1.119	92.28	0.10
Mycorrhiza	(M)	1	808.52**	0.19*	3086.46**	63379.63^{ns}	8.10**	0.59*	364.46**	0.80**
Zinc	(Zn)	2	196.16**	0.15*	2901.72*	512724.07**	14.78**	0.35*	201.52*	0.15^{ns}
Irrigation × Mycorrhiza	(I*M)	2	19.45^{ns}	0.003^{ns}	5839.68**	191001.85^{ns}	5.07*	3.303^{ns}	59.38^{ns}	0.31*
Irrigation × zinc	(I*Zn)	4	10.66^{ns}	0.002^{ns}	463.22^{ns}	59129.63^{ns}	0.69^{ns}	5.102^{ns}	4.29^{ns}	0.10^{ns}
Mycorrhiza × zinc	(M*Zn)	2	8.30^{ns}	0.017^{ns}	1099.24^{ns}	194124.07^{ns}	0.24^{ns}	2.117^{ns}	9.44^{ns}	0.16^{ns}
Irrigation × Mycorrhiza × Zinc	(I*Z*Zn)	4	9.94^{ns}	0.05^{ns}	489.12^{ns}	87396.30^{ns}	0.25^{ns}	4.05^{ns}	9.12^{ns}	0.28*
Sub-agent error	Error (b)	30	9.12	0.04	915.16	74155.56	0.38	2.04	5.16	0.08

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Coefficient of change (percent)	C.V		13.35	12.34	12.45	10.12	11.93	8.94	9.45	2.20

ns, *, **, respectively, are lack of significance, significant at a probability level of five and one percent

Table 2: Comparing the mean of the main effects of traits

Treatment	Plant height (cm)	Number of panicles per plant	Number of grains per panicle	Grain yield (kg/ha)	1000-grain weight (g)	Leaf chlorophyll content (mg/L)	The relative water content of leaf (%)	The protein content of grain (%)	Proline content (micromol / g fresh weight)	Harvest index (percent)
Water stress (I)										
I1	99.42 a	1.87 a	1314.38 a	7390 a	37.77 a	35.07 a	87.38 a	13.39 a	5.50 b	50.86 a
I2	89.89 b	1.67b	1219.88 b	6260 b	29.34 b	34.97 a	86.88 b	12.28 c	8.99 a	50.61 a
I3	80.36 c	1.51c	1158.88 c	6140 b	29.07 b	35.51 a	85.88 c	12.35 b	8.86 a	50.20 a
Mycorrhiza (M)										
M1	86.02 b	1.62 b	1207.14 b	6560 a	31.70 b	35.62 b	87.14 b	12.71 a	7.70 a	50.80 a
M2	93.76 a	1.74 a	1254.92 a	6630 a	32.48 a	36.74 a	85.96 a	12.64 a	7.86 a	50.31 a
Zn										
Zn_1	92.85 a	1.74 a	1231.33 ab	92.85 a	32.41 a	36.74 a	85.33 ab	12.76 a	7.63 a	50.13 b
Zn_2	90.48 b	1.73 a	1243.61 a	90.48 b	32.79 a	36.73 a	85.61 a	12.67 a	7.78 a	51.84 a
Zn_3	86.33 c	1.58 b	1218.22 b	86.33 c	31.07 b	34.58 b	84.22 b	12.60 a	7.85 a	49.70 b

The means that are common at least in one letter do not have a statistically significant difference in Duncan'smultiplerange test at the 5% probability level.

Chlorophyll content

Results indicated that leaf chlorophyll content was made significant by mycorrhiza and zinc application effect. Though, none of the interactions of experimental treatments had a significant statistical effect on chlorophyll content (Table 1).

The highest amount of chlorophyll belonged to mycorrhiza application with a mean of 36.74 mg/L, and the least amount of which belonged to the lack of mycorrhiza application with a mean of 35.64 mg/L (Table 2). Different levels of zinc changed the chlorophyll content of leaf so that the highest chlorophyll content belonged to zinc sulfate application with a mean of 34.74 and the lowest chlorophyll content belonged to distilled water application with an average of 34.58 mg/L (Table 2). When the plant faced with water shortage or stress, this problem disrupts the plant photosynthesis system and decreases chlorophyll content that according to the obtained results, it can be concluded that in the irrigation and stress conditions, by means of mycorrhiza, total chlorophyll increased compared to the control and by means of irrigating the plant and providing high and low application nutrients and

improving the pH of the soil and increasing the photosynthetic capacity, chlorophyll content of the plant increases (Pinior et al 2005; Bukvic et al 2003; Ruizluzano, 2003).
Marulanda et al. (2003) enumerate the reasons that lead to increasing the water use efficiency in mycorrhiza plants as follows:

1. In mycorrhiza plants, the plant's capacity to absorb more moisture and nutrients increases, which makes the openings to be open for a longer period and increases dry matter production.
2. In the mycorrhiza plants, the hydraulic conductivity of the root increases and the water is transmitted more efficiently.

Mycorrhiza, in addition to a significant effect on plant growth improvement, increases the absorption of nutrients. This upsurge in absorption in mycorrhiza plants, even when the soil phosphorus is high, can be seen. Mycorrhiza plant hyphae have the ability to absorb soil nitrogen and transform it into the root of the plants (Pinioret al. 2005; Bhoopander Giri 2017). Also, in severe environmental conditions, particularly drought stress, salinity and stress caused by heavy metals and environmental pollutants, and protecting host plant against pathogenic soil diseases mycorrhiza plays an important role.
(Pinior et al., 2005; Bhoopander, 2017) Bean plants coexist with mycorrhiza had a higher percentage of chlorophyll than non-mycorrhiza plants (Thakur and Panwar, 2003). Mamnouie et al (2006) in line with studying water deficit on the physiological traits performance of barley varieties showed that water deficit stress caused a decrease in grain yield and yield components, and water deficit caused an increase in the temperature inside the canopy and a decrease in chlorophyll content and irrigation was significant on the photochemical efficacy.

Relative water content

According to the results of trait variance analysis table, it was indicated that the relative water content of the plant was affected by mycorrhiza and Zn application was significant at 1% level, but none of the interactions of experimental treatments had a significant statistical effect on the leaves relative water content (Table 1).
Means comparison disclosed that under normal irrigation conditions, the leaf relative water content was 87.38% that was the highest percentage and water stress conditions had the lowest percentage (85.88%) (Table 2). Thus reducing the relative water content of the leaf during stress can be due to water stress in the under stress plant leaves because the environment dryness, by affecting stomatal conductance, reduces the water content of the tissue in leaves. The obtained results are consistent with the results of Kumar and Singh (1998). The higher relative water content of the leaf means the ability of the leaf to maintain greater amounts of water under drought stress conditions, and it is also a good indicator of selection in line with drought resistance. Because in the drought stress conditions, due to extreme plant transpiration and evaporation from the soil surface, the leaves relative water content decreases. According to the obtained results, it can be concluded that under irrigation and stress conditions, by increasing the relevant treatments, compared to the control, the leaf relative water content was increased, which is due to the fact that, under conditions of using mycorrhiza, the plant maintains more relative water in its leaves and increases the leaf relative

water content; consequently, by means of mycorrhiza application under irrigation and stress conditions, the plant will increase its stomatal resistance and water holding capacity, especially in leaf tissue, by absorbing water and food (especially phosphorus and potassium).

Among the different levels of mycorrhiza application, the highest amount of relative water content was obtained from mycorrhiza application treatment with a mean of 85.96 mm and the lowest value was 87.14 mm in the lack of mycorrhiza application treatment (Table 2).

Biological yield:

According to the results of traits variance analysis table, the biological yield traits were significantly affected by different levels of irrigation and mycorrhiza application, and the dual interactions effect of irrigation and mycorrhiza and the triple interactions effects of irrigation, mycorrhiza, and zinc in the level of one and five percent were significant, but the simple effect of Zn and other dual interaction effects of experimental treatments did not have a significant statistical difference on biological yield (Table 1).

Among the different levels of water stress, biological yield was affected so that the highest biological yield was obtained from total furrow irrigation with an average of 14.53 t/ha and the lowest biological yield with an average of 14.24 t/ha was related to rotational alternate irrigation, which did not have statistically significant difference with the fixed alternate irrigation treatment and was placed in a statistical class (Table 2). By means of mycorrhiza application, biological yield was affected and the highest biological yield with an average of 13.17 t/hawas obtained from mycorrhiza application treatment and the lowest amount with a mean of 12.93 t/hawas obtained from lack of mycorrhiza application treatment (Table 2).

The result of dual interaction effects of irrigation and mycorrhiza displayed that maximum biological yield, with the average of 14.66 t/ha, was belonged to total furrow irrigation with mycorrhiza application and the lowest amount with 12.23 t/ha belonged to rotational alternate irrigation with mycorrhiza application (Fig. 3).

According to the results of the trait variance analysis table, biological yield was significantly affected by different levels of irrigation and mycorrhiza application, and the dual interaction effect of irrigation and mycorrhiza and the triple interactions effect of irrigation, mycorrhiza and zinc element in the level of 1 and 5% were significant, but the simple effect of Zn and other dual interaction effects of experimental treatments did not have a significant difference on biological yield (Table 1).

Biological yield was influenced by the triple effects of irrigation, mycorrhiza, and Zn, so that the highest biological yield with the average of 14.83 t/ha belonged to total furrow irrigation treatment, with mycorrhiza application and zinc sulfate solution spraying, and the lowest value with an average of 11.96 t/ha belonged to fixed alternate irrigation without using mycorrhiza with zinc chelate (Fig. 4). According to the obtained results, it can be concluded that under irrigation and stress conditions, using the related treatments increase biological yield more than control which is due to improved nutrition, increased water absorption through increased root densities, hydrotherapy conductance within the root and water hyphae transfer to the roots, increased plant gas exchange, changes in soil water preservation properties, stimulation of assimilated activity necessary for plant growth (Ruizluzano , 2003).

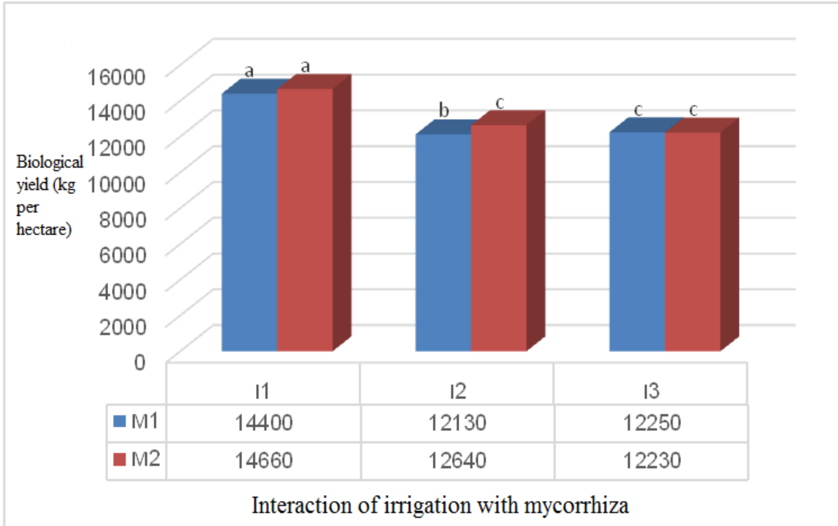

Figure 3: Interaction effects between different levels of irrigation and mycorrhiza on biological yield

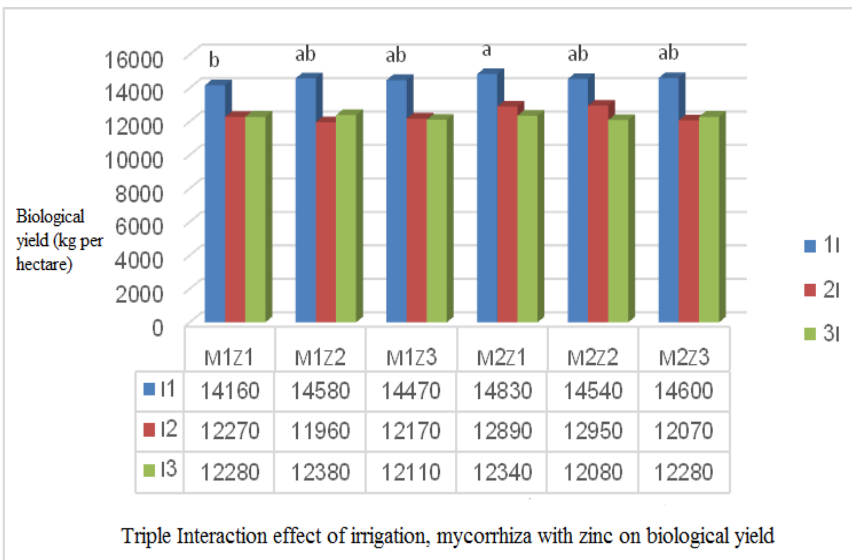

Figure 4: Triple Interaction effect of irrigation, mycorrhiza with zinc on biological yield

Grain protein content was significantly affected by different levels of irrigation ($P < 0.01$). But, mycorrhiza and zinc application and all double and triple effects of experimental treatments did not have a statistically significant difference in protein content ($P < 0.01$). Based on the results of the main effects mean comparison table, it was observed that the protein content of the grains was significantly affected by different levels of water stress, so that the highest protein content with an average of 13.29% obtained from the normal irrigation treatment and the lowest amount with an average of 12.28% obtained from fixed alternate irrigation (Table 2).

It seems that by applying drought stress and shortening the reproductive period, there is less opportunity for starch storage, and as a result, the grains protein content increases. In addition, according to several researchers, Zinc, by means of participating in the RNA polymerase structure, increased the amino acids and increased protein synthesis as a result increase protein content. Also due to drought stress, the amount of free nitrogen in the cell increased and the plant to prevent poisoning converts it to amino acids and ultimately proteins, which is why the protein increases (Thalooth et al., 2006).

Samarbakhsh (2009) investigated inoculation with different species of mycorrhiza on the growth and corn grain yield and reported that inoculation with mycorrhiza increased the protein content of the grains.

The results of traits variance analysis showed that proline was affected by different levels of irrigation and was significant at 1% level. But, the simple effect of mycorrhiza and zinc plus the double and triple interactions effects of experimental treatments did not exhibit a statistically significant difference on proline content (Table 1). The amount of proline was affected by an increase in the water stress intensity, and its amount increased, so that its maximum value with an average of 8.99 μ mol/g fresh weight belonged to fixed alternate irrigation treatment, which was statistically placed in a group with rotational alternate irrigation and they did not have any significant difference. The lowest amount of proline was obtained with an average of 5.50 μ mol/g fresh weight from total furrow irrigation treatment (Table 2).

Consistent with the results of the conducted research on corn, the results showed that drought stress could have a significant effect on nitrogen nutrient absorption, but mycorrhiza could have a positive influence on nitrogen absorption in corn, even under moisture stress conditions and increase these elements in the plant. In fact, the outside Mycelium of these fungi can be spread in the soil, and especially in small pores that are full of water and roots do not have access to them, they can transfer water to the host plant. In fact, the mycelium strands act as a soil moisture bridge (enclosed in fine pores) and a host plant (Widada et al., 2007).

In an experimental on sorghum, it was observed that in the presence of leaf water potential reaches to 14 to 16 times, changes can be formed in the amount of free proline in the leaves of this plant (Blum, 1979). According to a report (Ninganoor et al., 1995) in safflower plant it was approved that by applying drought stress, the amount of proline amino acid in the leaves of this plant increases, this increase is correlated with the decrease in the relative humidity of the plant and soil moisture, so that the dry matter causes a significant increase in the amount of proline in the leaves.

CONCLUSION:

In general, due to the obtained results, drought stress reduces the concentration of nutrients, but inoculation with mycorrhiza and zinc sulfate alone can moderate the adverse effects of drought stress in plants. Mycorrhiza by means of releasing its external mycelium in the fine pores of soila bsorbs water and nutrients and transfers them to the plant. Zinc affects the auxin hormone levels in the plant so that zinc deficiency in the plant reduces cell wall growth. Zinc also indirectly contributes to the formation of osmotic pressure and, in the absence of zinc; the water absorption by the plant will be limited.

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