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Research Article

The effect of mycorrhizal fungi on the yield and active ingredient of Borage (*Borago officinails L.*) under water deficit stress

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Abstract

In order to evaluate the effect of mycorrhizal fungi on the yield and active ingredient of borage (*Borago officinails L.*) under water deficit stress, the experiment conducted as split-plot in randomized complete block design with 3 replications in the Boyerahmad region at year 2015. The experiment factors were considered of irrigation levels (main-plot) as irrigation after S_1 =30, S_2 =60, S_3 =90, S_4 =120 and S_5 =150 mm water evaporation from evaporation pan class A and mycorrhiza fungi (sub-plot) were considered at the levels of non application (NM), application with mycorrhiza fungi species of *Glomus mosseae* (GM) and *Glomus intraradices* (GI). The results showed that the effect of water stress on flower yield of borage was significant at level 1% and in the treatment 30 mm evaporation was obtained the highest yield of flower (188.9 kg/ha). The most flower yield was obtained in application treatments of mycorrhizal fungus *G. Mossea* and *G. intraradices* respectively with flower yield 147.2 and 145.5 kg/ha compared to non application of mycorrhizal fungus. The interaction of water stress and mycorrhiza fungi on phytochemistry traits of mucilage weight and mucilage percent of flower borage was significant at level 1%. The treatments S_{30}N.G, S_{30}GM, S_{30}GI, S_{90}N.G, S_{90}GM and S_{90}GI respectively with the weight of flower mucilage 11.77, 12.47, 12.06, 10.32, 12.34 and 11.78 kg/ha with the highest value were in first class (A). Treatments S_{30}N.G, S_{30}GM, S_{30}GI, S_{60}N.G, S_{60}GM, S_{60}GI, S_{90}GM, S_{90}GI and S_{120}GM respectively with flower phosphorus content 268.4, 290.1, 275.6, 253.9, 252.9, 282.9, 268.9, 192.4 and 174.3 ppm had the highest amount. The treatments S_{90}GM and S_{90}GI respectively with water use efficiency 0.0178 and 0.0176 kg/m^3 had the highest amount. The application of mycorrhizal fungi generally reduced the negative effects of water stress in this study and could increase flower yield, water use efficiency, percentage and weight of flower mucilage of borage in this research.

Keywords: Flower phosphorus, Flower yield, Mucilage, Water use efficiency

Introduction

Among the environmental factors hindering the growth and yield of plants of agronomic, horticultural and medicinal, drought considered the most important factor of production decline, especially in arid and semi arid areas (Reddy *et al*., 2004). Chang of planting patterns and the use of alternative species including medicinal plants tolerant to drought stress could be to provide possible of efficient use of limited water resources (Jami Ahmadi *et al*., 2005). In stress condition, mycorrhizal fungi causes accounted more carbon for root plant and therefore increase root growth and expansion of its length due to the increase in surface area of root with soil and thus increase absorb of water and nutrients in the root discharge area (Koucheki *et al*., 2012).

Heidari and Minaei (2015) showed that application of water stress up to 70% of field capacity (FC) cause increase flower yield, biomass yield and yield of flowering shoot and also cause a high concentration of phosphorus in borage. With increasing of stress intensity and reach moisture soil to 50% of field capacity, also decreased values of these traits. In one study, borage plant biomass under drought stress treatments of 120 and 150 mm evaporation of evaporation pan had decreased significantly. The increase water restrictions cause reduceing 31.8 to 60.2 percent dry weight of seed (Dastborhan *et al*., 2013).

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Bahreininejad *et al*. (2013) showed that water stress was reduced growth and foliage production of thyme, while water use efficiency was increased. In a review with study irrigation regimes on chamomile showed that the highest percentage of essential oil, dry flower yield and essential oil yield was obtained from irrigation at 85% field capacity, but the significant difference did not report between irrigation treatments in 85% and 75% of field capacity. Drought stress reduced flower yield of chamomile (Baghalian *et al*., 2011). Based on the results of one experiment, effects of deficit stress and bio-fertilizers on harvest index of the flowering branches and seed harvest index of Borage was significant, but treatments interaction was not significant. In between treatments of deficient water stress, the highest harvest index for the flowering branches and seed was observed in treatment without stress. The lowest harvest index for the flowering branches and seed was observed in treatments including vegetative + reproductive stress. Based on the results, water stress cause reduces the harvest index and consumption of bio-fertilizers increased harvest index of Borago medicinal plant (Karami and Sepehri, 2014).

The results of one research showed that mycorrhiza fungi *G. mosseae* cause increase biomass yield of *Mentha pulegium* medicinal plant under drought stress (Khaosaad *et al*., 2006). A study showed that sorghum harvest index was affected by the treatments of irrigation and mycorrhizal fungi, So that most of the harvest index belonging to the species G. *mossea* (Hamzei and Sadeghi Myabadi, 2014). Agha Alikhani *et al*. (2014) found that the use of bio-fertilizers (biosphere and Nitroxen) increased the yield of *Echinacea*. Aslani *et al*. (2011) with study the effect of mycorrhizal fungus *G. mosseae* and *G. intraradices* on phosphorus uptake of basil (*Ocimum basilicum* L.) under drought conditions found that inoculated plants with *Arbuscular mycorrhizal* fungi compared with non-inoculated plants, increased growth, yield and P uptake under drought stress and non-stress conditions. The effect of *G. mosseae* fungi in reducing the impact of drought was more than *G. intraradices* fungi.

According to the results of a study, two species of fungi *G. macrocarpum* and *G. fasciculatum* increased the amount of phosphorus in the shoots of *Artemisia* medicinal plant and with the development of foliage was increased dry matter yield of this plant and improve water use efficiency (WUE) under stress conditions (Chaudhary *et al*., 2007). The results of investigation of Ahmadinejad *et al*. (2014) showed that the effect of irrigation regimes was not significant on agronomic WUE of *Sesamum indicum* grain. The Impact of the application of mycorrhizal fungi *G. mosseae* on agronomic WUE of grain crop was significant. The highest agronomic WUE of grain (0.74 kg/m^3) was related to irrigation regimes supply of 80 percent of soil moisture shortage and mycorrhiza fungi symbiosis. Ghasemi *et al*. (2012) showed that the highest mucilage yield of medicinal plant of *Plantago psyllium* respectively with 931 and 166 kg/ha mucilage was obtained with application mycorrhizal. Motahari *et al*. (2012) found that the yield of the active ingredients of calendula medicinal plants was obtained in the effect of consumption of mycorrhizal *G. fasciculatum*. Ghasemi Syani *et al*. (2012) showed that the effect of irrigation intervals on the percentage of *Plantago psyllium* mucilage was significant. The highest percentage of *Plantago psyllium* mucilage was obtained with irrigation 7 and 14 days respectively.

Borage is a medicinal plant that because of its health benefits and good taste greatly used among people of many different countries. The most important challenge in producing this plant is lack of awareness of how cultivate, also the effect of important environmental parameters on this plant. Since drought is one of the factors affecting on agricultural development of Kohgiluyeh and Boyerahmad region and also because of the effective role of mycorrhizal fungi in improving the yield of some plants under water stress was conducted this study in the Boyerahmad region.

Materials and methods

The experiment conducted as split-plot in randomized complete block design with 3 replications in the Boyerahmad region and at year 2015. The experiment factors were considered of irrigation levels (main plot) as irrigation after S_1 =30, S_2 =60, S_3 =90, S_4 =120 and S_5 =150 mm water evaporation from evaporation pan class A and mycorrhiza fungi (sub-plot) were considered at the levels of non application, application with mycorrhiza fungi species of *G. mosseae* and *G. intraradices*. After plowing and seedbed preparation, plots were obtained with dimensions of 3×5 m. The distance between the experimental main plots of 3 m, subplots 1 m and distance between repetitions 3 m were considered. Before sowing the seeds of borage, about 7 grams of inoculants containing mycorrhizal fungal spores (clinic production of organic plant protection of Asadabad in Hamadan with registration number 27.1554) were cast in each hole of borage planting (Enteshari and Haji Hashim, 2011).

Borage seed were planting in the first half of April and with plant spacing between row and on row 50 × 30 cm (Karami and Sepehri, 2014). Planting operations were performed manually and as furrow and stack. Until the emergence, irrigation was performed once in every two days. After germination and seedling establishment (trifoliate stage), thinning and weed control operations were carried out. Then the irrigation treatments were applied. The flower yield, biological yield were calculated at 100% flowering time, then flower harvest index (flower harvest index= flower yield/ biological yield × 100) were calculated. In this study, after measuring the total amount of water consumed per subplots and measurement of borage flower yield, WUE (kg/m^3) = flower yield / total water consumption) was calculated (Alizadeh, 2012).

For measurement phosphorus content of flowers at

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100% flowering time was used to plant ash. To conduct this research, in first a few drops of distilled water was poured on the ashes of one gram of dry matter into the Chinese jar. Then in order to solve the plant ash was added to it 2 ml nitric acid 1: 2 and was worn with a nice glassy rods. The resulting solution was flat through a filter paper into a balloon 100 ml. Inside the jars washed with a few ml of distilled water and the solution was poured on filter paper and was added to the acidic solution of ash inside the balloons. The resulting solution was neutral with ammonia 1: 1, then 5 ml nitric acid 1: 2 and 15 ml represents vanadate molydate were added to it and the final volume of solution was brought to100 ml with distilled water. The above solution absorption was measured at wavelength 450 nm by a spectrophotometer model UV/VIS 911. Also, standard solutions absorption was measured at wavelength 450 nm. Control for sample solution of ash and standard solution is standard solution 0 ppm. For draw a standard curve, obtained numbers from absorbance of standard solution was used on Y-axis and also obtained numbers from absorbance of the standard solution concentration was used on the X axis and standard curves were plotted, then with the help of standard curve was determined the amount of plant samples phosphorus in according to ppm (Method spectrophotometer, Askari and Amini, 2011).

At 100% flowering time in order to determine the percentage of flowers mucilage, 5 g of ground dried plant was poured in beakers and 100 ml of distilled water added to it and stored in the refrigerator for 24 hours. 100 ml of 95% ethanol was added to 50 ml of the filtrated fluid and again stored in the refrigerator for 24, until the mucilage available was deposited. After this period, was filtrated on filter paper that already was weight and after drying at 105 °C temperature was weight of filter paper and mucilage. In order to determine the percentage of mucilage, filter paper containing mucilage put into human and it is washed by 100 ml of distilled water to remove the mucilage in that of the filter paper and mucilage remains as precipitation. After drying the filter paper, carefully weighed and percent of mucilage was calculated of the difference between the weights of filter paper with the initial weight (Samsam Shariat, 2008). Data analysis using the software *MSTATC* and comparison of means was performed by Duncan's multiple range tests.

Results and discussion

The main effect of water deficit stress on the flowers yield of Borage plant is significant at level 1% (Table 1), as shown in figure 1, also was observed this significant difference and at the treatment 30 mm evaporation of evaporation pan was obtained the highest flower yield (188.9 kg/ha) in class A and the lowest flower yield (52.44 kg/ha) was harvest in the treatment of 150 mm evaporation of evaporation pan and placed in the last class. Of course Heidari and Minaei (2015) with investigation the effect of drought stress on flowers yield and concentration of macro nutrients elements in Borage (*Borago officinalis L.*) showed that application of water stress up to 70% of field capacity cause increase flower yield, biomass yield and yield of flowering shoot. With increasing stress intensity and reach moisture soil to 50% of field capacity, also decreased values of these traits. Akbarinia *et al*. (2008) showed that by increasing watering times, flower yield of *Echium amoenum* increased. The highest and lowest flower yield of this plant respectively related to treatments of once irrigation in 7 day and non-irrigation. The flowering period in conditions of once irrigation in 7 day was more than non-irrigation conditions. In another study showed that drought stress reduced flower yield of *chamomile* (Baghalian *et al*., 2011).

The main effect of mycorrhizal fungi on Borage flower yield was significant at 1% level (Table 1). The lowest flower yield (104.6 kg/ha) was obtained in the treatment of non application of mycorrhizal fungi and the highest flower yield dedicated at the treatment of application of mycorrhizal fungi *G. mossea* and *G. intradices* reapectively with flower yield (147.2 and 145.5 kg/ha) that placed in first class, of course mycorrhizal fungi *G. mossea* with a minor difference gained more flower yield than *G. intradices* fungi (figure 2). Agha Alikhani *et al*. (2014) found that the use of bio-fertilizers (biosphere and nitroxen) increased the yield of *Echinacea*. Also according to the results of a study, two species of fungi *G. macrocarpum* and *G. fasciculatum* increased the amount of foliage of *Artemisia* medicinal plant (Chaudhary *et al*., 2007).

The interaction of water stress and mycorrhizal fungi on the flower yield of Borage was also significant at 1% level (Table 1) and in accordance with comparison table of interaction were created significant changes in the flower yield. Treatments S_{30}N.G, S_{30}GM, S_{30}GI, S_{60}GM, S_{60}GI, S_{90}GM and S_{90}GI respectively with the flower yield 187.8, 190.3, 188.7, 190.3, 187, 187.3 and 185.3 kg/ha with the highest value was in first class, but treatment S_{150}N.G with the flower yield 34.67 kg/ha placed in the last class E and had the lowest the flower yield (figure 3). In one study, Borage plant biomass under drought stress treatments of 120 and 150 mm evaporation of evaporation pan had decreased significantly (Dastborhan *et al*., 2013). Aslani *et al*. (2011) with study the effect of mycorrhizal fungus *G. mosseae* and *G. intraradices* on phosphorus uptake of Basil (*Ocimum basilicum* L.) under drought conditions found that *Arbuscular mycorrhizal* fungi inoculation plants compared with non-inoculated plants, had more yield under drought stress and non-stress conditions. The effect of *G. mosseae* fungi in reducing the impact of drought was more than *G. intraradices* fungi. Jalilvand *et al*. (2012) showed that drought stress had significant effect on growth parameters and vegetative yield of *Satureja* and with increasing drought stress decreased shoot dry weight. In general, the application of mycorrhiza fungi increased resistance to drought stress in *Satureja* plant.

Table 1. The results of variance Analysis

Source of variations	d.f	Mean Squares						
		Flower yield	Biological yield	Harvest index	water use efficiency	Phosphorus content	Mucilage percent	Mucilage weight
Replication	2	10.689 ns	344425.492 ns	0.042 ns	0.133 ns	12059.399ns	0.949 ns	10.590 ns
Water stress (A)	4	31175.833**	17776011.596**	1.249**	0.112405**	72730.185**	21.801**	169.949**
Error	8	8.300	194765.622	0.235	0.000113	4396.999	0.145	7.555
mycorrhizae fungi (B)	2	8732.689**	3599853.597**	0.705*	0.082731**	10342.247**	2.539**	16.173**
(AB)	8	1040.883**	286074.187**	0.414**	0.009825**	741.096**	0.265**	1.814*
Error	20	51.678	390803.513	0.244	0.000435	2711.848	0.370	6.525
Cv%		5.43	17.24	13.80	6.12	28.66	10.88	32.83

***, ** and ns Significant level, refer to 0.5%, 0.1% and no significant, respectively**

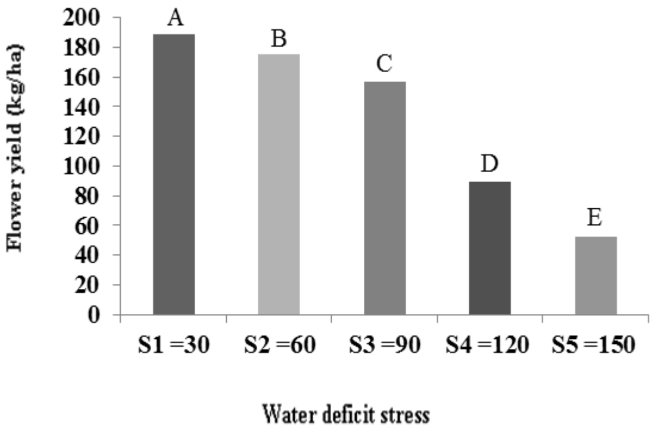

Figure 1. The main effect of water deficit stress on the flowers yield

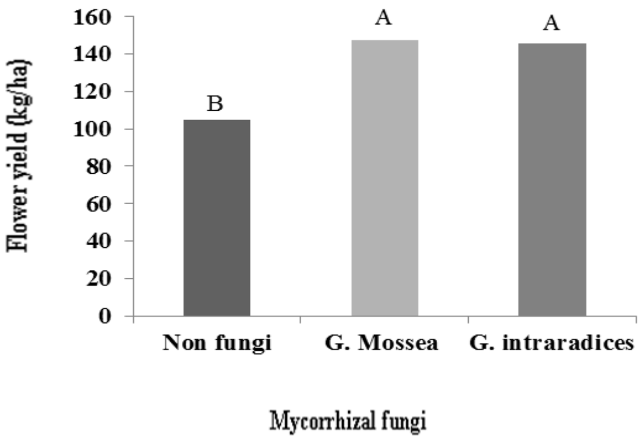

Figure 2. The main effect of mycorrhizal fungi on the flowers yield

The water stress had significant effect on flower biological yield of Borage at the level 1% (Table 1). Treatments 30 and 60 mm evaporation respectively with flower biological yield 5131 and 4653 kg/ha with the most amount placed in class A and treatment 150 mm evaporation with the lowest flower biological yield (5131 kg/ha) placed in class last C (figure 4) and can be found that increasing of water deficit stress was reduced flower biological yield of Borage. Bahreininejad *et al*. (2013) showed that water stress was reduced growth and foliage production of thyme. Jalilvand *et al*. (2012) showed that drought stress had significant effect on growth parameters and vegetative yield of *Satureja* and with increasing drought stress decreased shoot dry weight. In general, the application of mycorrhiza fungi increased resistance to drought stress in *Satureja* plant.

The main effect of mycorrhizal fungi on flower biological yield of Borage was significant at level 1%

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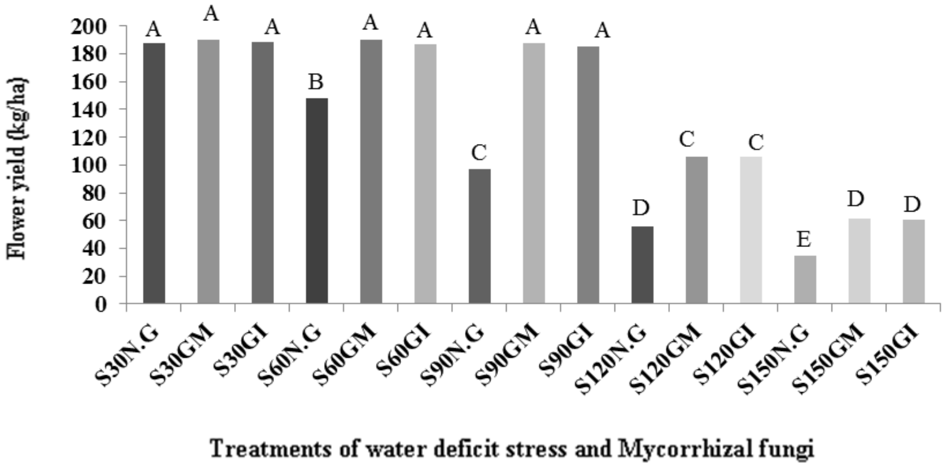

Figure 3. The interaction of water deficit stress and mycorrhizal fungi on the flower yield

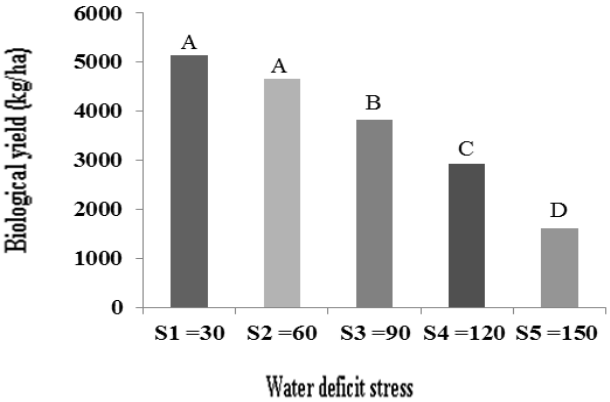

Figure 4. The main effect of water deficit stress on the biological yield

(Table 1). The most flower biological yield (3911 and 3908 kg/ha) was harvest in the application treatments of mycorrhizal fungi *G. mossea* and *G. intradices* reapectively and the lowest flower biological yield (3061 kg/ha) was related to non application treatment of mycorrhizal fungi (figure 5). The results of one research showed that mycorrhiza fungi *Glomus mosseae* cause increase biomass yield of *Mentha pulegium* medicinal plant under drought stress (Khaosaad *et al*., 2006).

According to the results of a study, two species of fungi *Glomus macrocarpum* and *Glomus fasciculatum* cause the development of foliage and increased dry matter yield of Medicinal plant Artemisia (Chaudhary *et al*., 2007). Agha Alikhani *et al*. (2014) found that the use of bio-fertilizers (*Biosphere* and *Nitroxen*) was to increase the yield of *Echinacea*. The interaction between mycorrhizal fungi and water stress on flower biological yield of Borage also was significant at level 1% (table 1) and in accordance with the average comparison table of interaction were created significant changes in the flower biological yield. Treatments S_{30}N.G, S_{30}GM, S_{30}GI, S_{60}N.G, S_{60}GM, S_{60}GI, S_{90}GM and S_{90}GI, respectively with flower biological yield 5124, 5135, 5134, 3692, 187, 5134, 5134, 4121 and 4118 kg/ha with the highest amount were in first class, but treatments S_{150}N.G, S_{150}GM and S_{150}GI, respectively with flower biological yield 1114, 1868 and 1864 kg/ha were in the last classes E and had the lowest flower biological yield (figure 6). The results of Shah Hossini *et al*. (2013) showed that symbiotic mycorrhizal fungi (*G. mosseae* and *G. intraradices*) in water stress conditions increased dry matter accumulation of corn, while this trait decreased in drought stress conditions and without mycorrhizal symbiosis. Aslani *et al*. (2011) found that *Arbuscular mycorrhizal* fungi inoculation plants compared with non-inoculated plants, had the more growth, more yield under drought stress and non-stress conditions. The effect of *G. mosseae* fungi in reducing the impact of drought was more than *G. Intraradices* fungi.

The main effect of water stress on the harvest index of Borage plant is significant at level 1% (Table 1), so that by looking at the figure 7 of comparison of the main effects, also was observed this significant difference and at the treatments 30, 60 and 90 mm evaporation of evaporation pan was obtained highest the harvest index (3.701, 3.706 and 4.074) in class A and the lowest harvest index (3.173 and 3.241) respectively was harvest in the treatment of 120 and 150 mm evaporation of evaporation pan and placed in the last

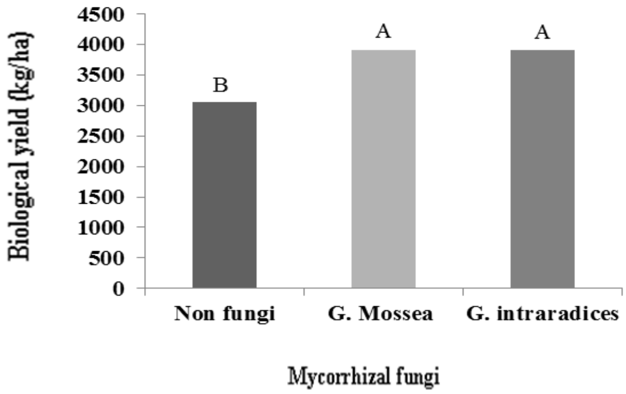

Figure 5. The main effect of mycorrhizal fungi on the biological yield

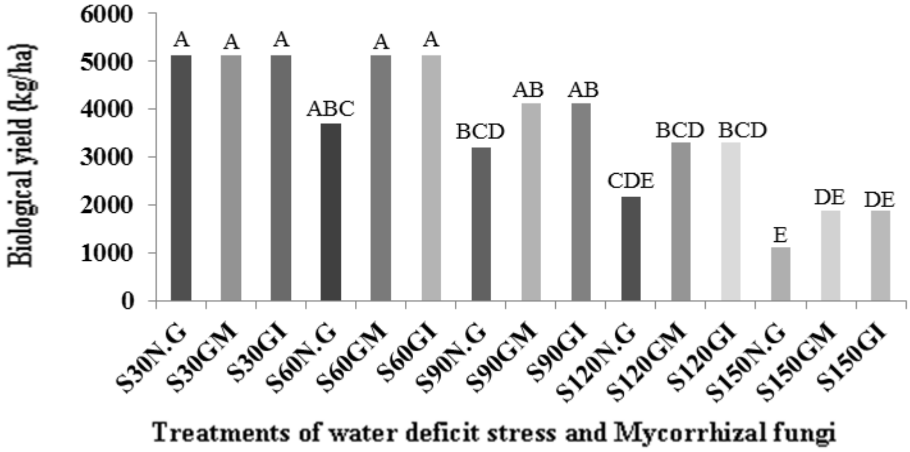

Figure 6. The interaction of water deficit stress and mycorrhizal fungi on the biological yield

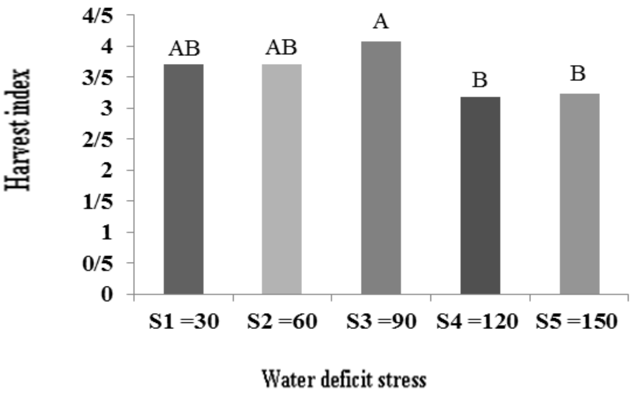

Figure 7. The main effect of water deficit stress on the harvest index

class. Based on the results of one experiment, the effect of deficit stress on harvest index of the flowering branches and seed harvest index of Borage was significant. In between treatments of deficient water stress, the highest harvest index of the flowering branches and seed was observed in treatment without stress. The lowest harvest index for the flowering branches and seed was observed in treatments including vegetative + reproductive stress (Karami and Sepehri, 2014). The results of the Mobasser and Tavasoli (2013) showed that the effect of drought stress on corn harvest index was significant and drought stress decreased corn harvest index. Another report found that drought stress reduced corn harvest index (Sajedi and Madani, 2006).

The main effect of mycorrhizal fungi on harvest index was significant at level 5% (Table 1). The lowest harvest index (30.330) was obtained in the treatment of non application of mycorrhizal and the highest harvest

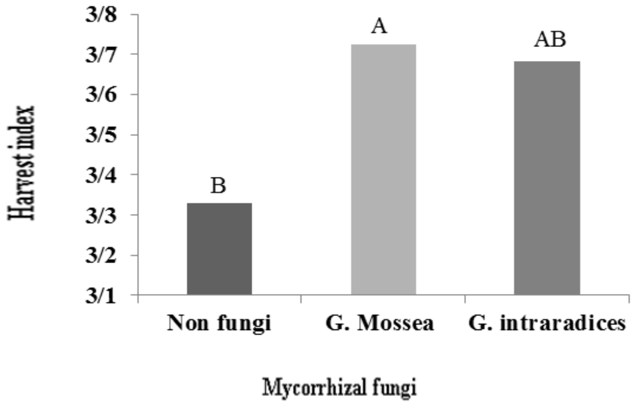

Figure 8. The main effect of mycorrhizal fungi on the harvest index

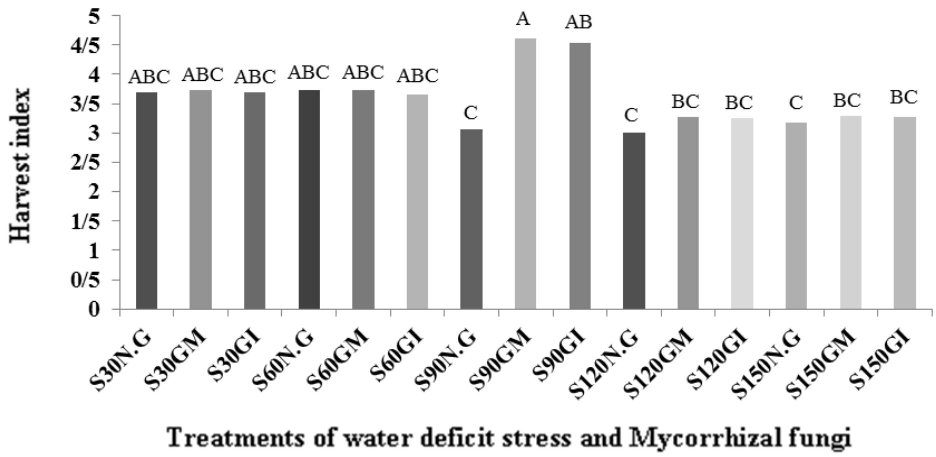

Figure 9. The interaction of water deficit stress and mycorrhizal fungi on the harvest index

index dedicated at the treatment of application of mycorrhizal fungi *G. mossea* and *G. intradices* reapectively with harvest index (3.725 and 3.683) that placed in first class, of course mycorrhizal fungi *G. mossea* with a minor difference, gained more harvest index than *G. intradices* fungi (figure 8).

The interaction of water stress and mycorrhizal fungi on the harvest index of borage was also significant at level 1% (Table 1) and in accordance with the comparison figure 9 of interaction were created significant changes in the harvest index. Treatments of S_{30}N.G, S_{30}GM, S_{30}GI, S_{60}N.G, S_{60}GM, S_{60}GI, S_{90}GM and S_{90}GI respectively with the harvest index 3.683, 3.723, 3.697, 3.730, 3.727, 3.660, 4.613 and 4.540 with the highest value were in first class, but treatments of S_{90}GI, S_{120}GI and S_{30}GI respectively with the harvest index 3.070, 3 and 3.167 placed in the last class C and had the lowest the harvest index. A study showed that sorghum harvest index was affected by the treatments of irrigation and mycorrhizal fungi. So that most of the harvest index belonging to the species *G. mossea* (Hamzei and Sadeghi Myabadi, 2014). The results of the Mobasser and Tavasoli (2013) showed that the effect of drought stress and mycorrhizal fungi on corn harvest index was significant and drought stress decreased corn harvest index, but mycorrhizal fungi increased this trait. Based on the results of one experiment, water stress cause reduced the harvest index and consumption of bio-fertilizers increased harvest index of borago medicinal plant (Karami and Sepehri, 2014).

The main effect of water stress on the flower water use efficiency of Borage medicinal plant is significant at level 1% (Table 1), so that by looking at the figure 10 of comparison of the main effects, also was observed this significant difference and at the treatment 90 mm evaporation of evaporation pan was obtained highest the flower water use efficiency (0.0149 kg/m^3) in class A and the lowest flower water use efficiency (0.0061 kg/m^3) was harvest in the treatment of 150 mm evaporation of evaporation pan and placed in the last class D. Akbarinia *et al*. (2008) found WUS in once irrigation in14 day compared to the once irrigation in14 day and other treatments had the highest amount. Bahreininejad *et al*. (2013) showed that water stress reduced growth and foliage production of thyme, while WUS was increased. The main effect of mycorrhizal fungi on the flower WUS of borage was significant at level 1% (Table 1). The lowest WUS of flower (0.008 kg/m^3) was obtained in the treatment of non application

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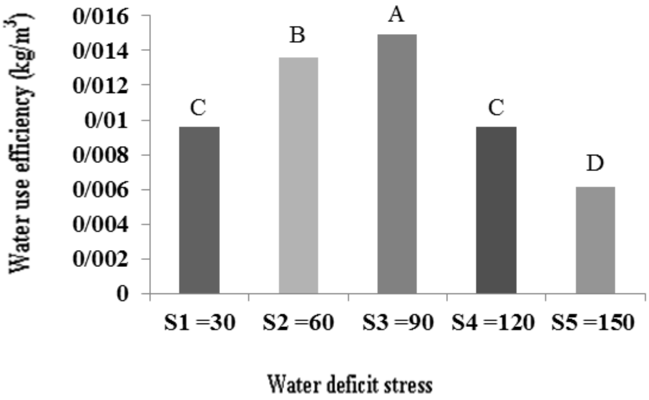

Figure 10. The main effect of water deficit stress on the water use efficiency

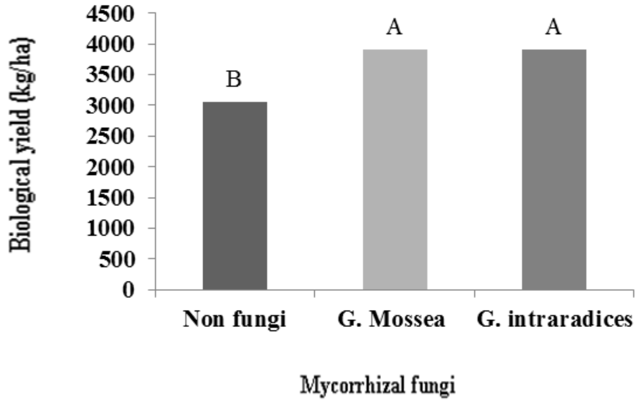

Figure 11. The main effect of mycorrhizal fungi on the water use efficiency

of mycorrhizal and the highest WUS of flower dedicated at the treatment of application of mycorrhizal fungi *G. mossea* and *G. intradices* reapectively with WUS of flower (0.0122 and 0.0120 kg/m^3) that placed in first class, of course mycorrhizal fungi *G. mossea* with a minor difference, gained more WUS of flower than *G. intradices* fungi (figure 11). According to the results of a study, two species of fungi *G. macrocarpum* and *G. fasciculatum* increased the amount of phosphorus in the shoots of *Artemisia* medicinal plant and with the development of foliage was increased dry matter yield of this plant and improved water use efficiency under stress conditions (Chaudhary *et al*., 2007).

The interaction of water stress and mycorrhizal fungi on the flower water use efficiency of borage are also significant at level 1% (Table 1) and in accordance with the comparison figure 12 of interaction were created significant changes in the WUS of flower. Treatments S_{90}GM and S_{90}GI respectively with the WUS of flower 0.0178 and 0.0176 kg/m^3 with the highest value was in first class (A), but treatment S_{150}N.G with the WUS of flower 0.0040 kg/m^3 placed in the last class F had the lowest the WUS of flower. The results of investigation of Ahmadinejad *et al*. (2014) showed that the effect of irrigation regimes was not significant on agronomic WUS of *Sesamum indicum* grain. The impact of the application of mycorrhizal fungi *G. mosseae* on agronomic WUS of grain crop was significant. The highest agronomic WUS of grain (0.74 kg/m^3) was related to irrigation regimes supply of 80 percent of soil moisture shortage and mycorrhiza fungi symbiosis. The results of Shah Hossini *et al*. (2013) showed that symbiotic mycorrhizal fungi (*G. mosseae* and *G. intraradices*) in water stress conditions increased dry matter accumulation of corn, while this trait decreased in drought stress conditions and without mycorrhizal symbiosis. Mycorrhizal inoculation significantly increased WUS. The interaction of mycorrhizal symbiotic and drought stress was significant on WUS in corn. The most WUS was obtained of the use of *G. mosseae* and severe drought conditions and the lowest was obtained from control plants under non stress.

The water stress had significant effect on phosphorus content of borage flowers at the level of 1% (Table 1). Treatments 30, 60 and 60 mm evaporation respectively with flower phosphorus content 278 ppm, 268 ppm and 170.6 ppm with the most amount placed in class A and treatments 120 and 150 mm evaporation with the lowest flower phosphorus content 113 ppm and 78.31 ppm placed in last class B (figure 13) and found that increasing of water deficit stress reduced phosphorus content of borage flowers. Jalilvand *et al*. (2012) showed that drought stress had significant effect

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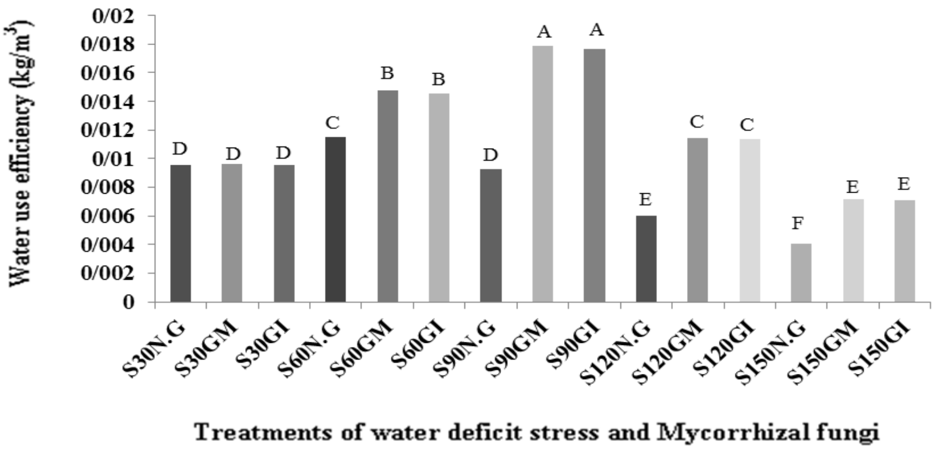

Figure 12. The interaction of water deficit stress and mycorrhizal fungi on the water use efficiency

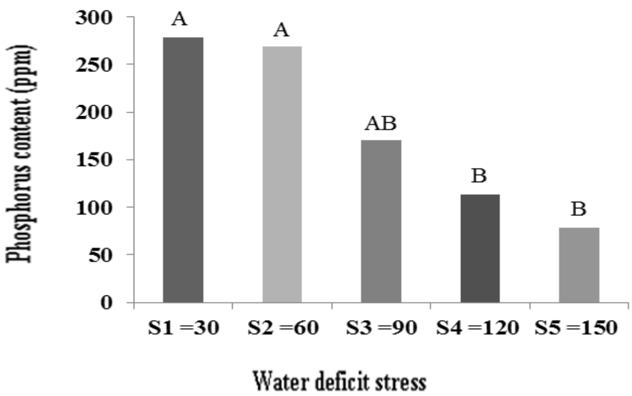

Figure 13. The main effect of water deficit stress on the phosphorus content

on leaf phosphorus content of *Satureja* and with increasing drought stress decreased leaf phosphorus content. The main effect of mycorrhizal fungi on phosphorus content of borage flowers was significant at level 1% (Table 1). The most flower phosphorus content (204.7 and 187.3 ppm) was harvest in the application treatments of mycorrhizal fungi *G. mossea* and *G. intradices* respectively and the lowest flower phosphorus content (153.1 ppm) was relate to non-application treatment of mycorrhizal fungi (figure 14). Of course according to the results of a study, two species of fungi *G. macrocarpum* and *G. fasciculatum* increased the amount of phosphorus in the shoots of *Artemisia* medicinal plant (Chaudhary *et al*., 2007). However, Jalilvand *et al*. (2012) showed that inoculated *Satureja* plant with mycorrhiza fungi, increased phosphorus content of *Satureja* plant in drought conditions compared with non-inoculated plants significantly.

The interaction between mycorrhizal fungi and water stress on flower phosphorus content of Borage also was significant at 1% level (Table 1) and in accordance with the average comparison table of interaction were created significant changes in the flower phosphorus content. Treatments S_{30}N.G, S_{30}GM, S_{30}GI, S_{60}N.G, S_{60}GM, S_{60}GI, S_{90}GM, S_{90}GI and S_{120}GM respectively with flower phosphorus content 268.4, 290.1, 275.6, 253.9, 252.9, 282.9, 268.9, 192.4 and 174.3 ppm with the highest amount were in first class, but treatment S_{150}N.G with flower phosphorus content 34.83 ppm was in the last class E and had the lowest flower phosphorus content (figure 15). Aslani *et al*. (2011) with study the effect of mycorrhizal fungus *G. mosseae* and *G. intraradices* on phosphorus uptake of basil (*Ocimum basilicum* L.) under drought conditions found that *Arbuscular mycorrhizal* fungi inoculation plants compared with non-inoculated plants, had the more P uptake under drought stress and non-stress conditions. The effect of *G. mosseae* fungi in reducing the impact of drought was more than *G. intraradices* fungi.

The main effect of water stress on the flower mucilage percentage of borage medicinal plant is significant at level 1% (Table 1), so that by looking at the figure 16 of comparing the average, also was observed this significant difference and at the treatments 30 and 60 mm evaporation respectively was obtained highest the percentage of flower mucilage (7.034%, and 6.678%) in class A and the lowest percentage of flower mucilage (4.512%) was harvest in the treatment of 150

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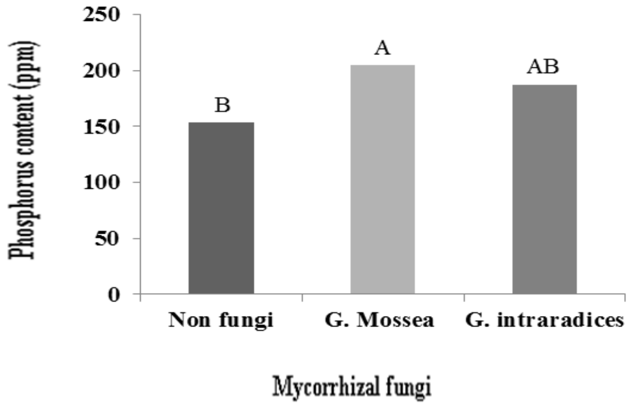

Figure 14. The main effect of mycorrhizal fungi on the phosphorus content

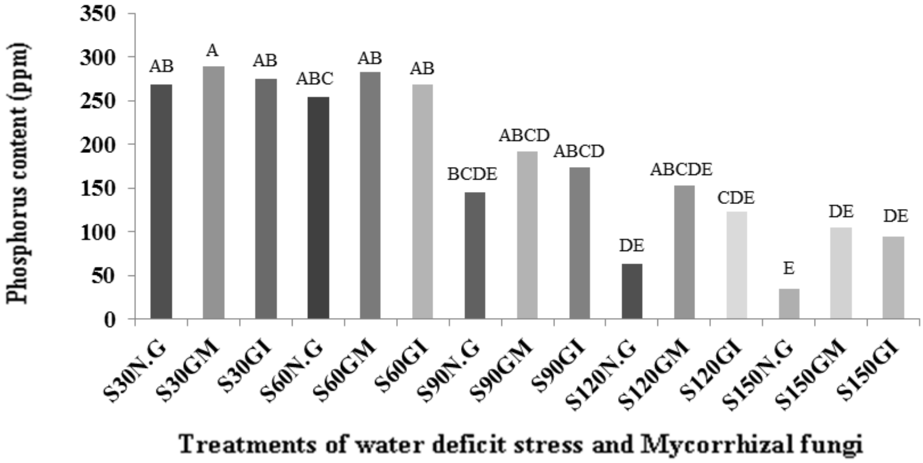

Figure 15. The interaction of water deficit stress and mycorrhizal fungi on the phosphorus content

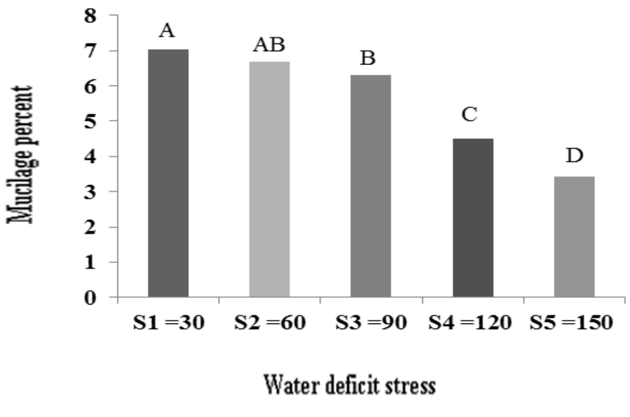

Figure 16. The main effect of water deficit stress on flower mucilage percentage

mm evaporation and placed in the last class C. The main effect of mycorrhizal fungi on the mucilage percentage of borage flower was significant at level 1% (Table 1). The lowest percentage of flower mucilage (5.115%) was obtained in the treatment of non application of mycorrhizal and the highest percentage of flower mucilage dedicated at the treatment of application of mycorrhizal fungi *G. mossea* and *G. intradices* reapectively respectively with percentage of flower mucilage (5.847% and 5.807%) that placed in first class, of course mycorrhizal fungi *G. mossea* with a minor difference, gained more percentage of flower mucilage than *G. intradices* fungi (figure 17). The interaction of water stress and mycorrhizal fungi on the flower mucilage percentage of borage are also significant at level 1% (Table 1) and in accordance with the average comparison table of interaction were created significant changes in the percentage of flower mucilage.

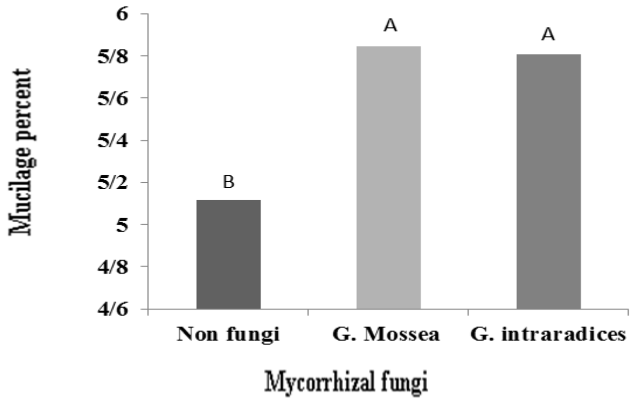

Figure 17. The main effect of mycorrhizal fungi on flower mucilage percentage

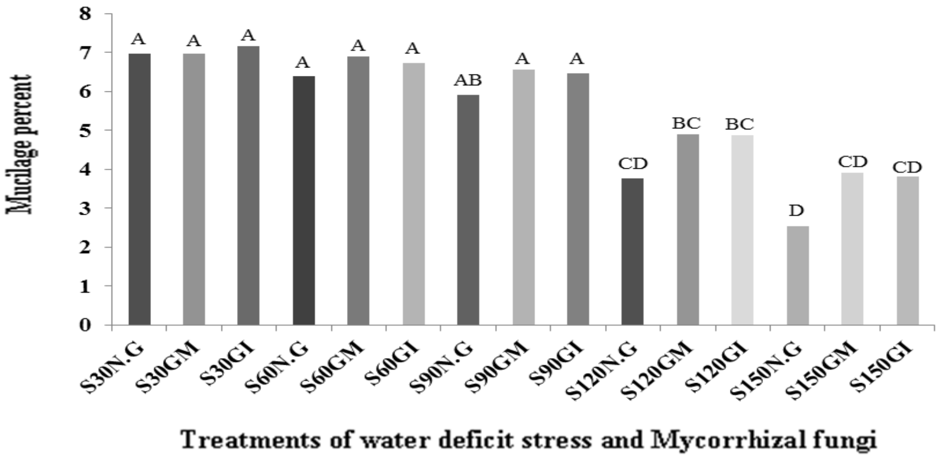

Figure 18. The interaction of water deficit stress and mycorrhizal fungi on flower mucilage percentage

Treatments S_{30}N.G, S_{30}GM, S_{30}GI, S_{60}N.G, S_{60}GM, S_{60}GI, S_{30}N.G, S_{90}GM and S_{90}GI respectively with the percentage of flower mucilage 6.970%, 6.967%, 7.167%, 6.4%, 6.9%, 6.733%, 5.9%, 6.567% and 6.467% with the highest value was in first class (A), but treatment S_{150}N.G with the percentage of flower mucilage 2.540% placed in the last class D and had the lowest the percentage of flower mucilage (figure 18).

The main effect of water stress on the flower mucilage weight of borage medicinal plant is significant at level 1% (Table 1), so that by looking at the figure 19 of comparing the average, also was observed this significant difference and at the treatments 30, 60 and 60 mm evaporation of evaporation pan was obtained highest the weight of flower mucilage (12.10, 11.48 and 8.770 kg/ha) in class A and the lowest weight of flower mucilage (4.189 and 2.367 kg/ha) was harvest in the treatment of 120 and 150 mm evaporation of evaporation pan and placed in the last class B. The main effect of mycorrhizal fungi on the flower mucilage weight of borage was significant at level 5% (Table 1). The lowest weight of flower mucilage (6.674 kg/ha) was obtained in the treatment of non application of mycorrhizal and the highest weight of flower mucilage dedicated at the treatment of application of mycorrhizal fungi *G. mossea* and *G. intradices* reapectively with weight of flower mucilage (8.733 and 7.936 kg/ha) that placed in first class, of course mycorrhizal fungi *G. mossea* with a minor difference, gained more weight of flower mucilage than *G. intradices* fungi (figure 20). The interaction of water stress and mycorrhizal fungi on the flower mucilage weight of borage are also significant at level 1% (Table 1) and in accordance with the average comparison table of interaction were created significant changes in the weight of flower mucilage. Treatments S_{30}N.G, S_{30}GM, S_{30}GI, S_{90}N.G, S_{90}GM and S_{90}GI respectively with the mucilage weight of flower 11.77, 12.47, 12.06, 10.32, 12.34 and 11.78 kg/ha with the highest value were in first class (A), but treatment S_{150}N.G with the weight of flower mucilage 1.01 kg/ha placed in the last class D and had the lowest the weight of flower mucilage (figure 21). Ghasemi *et al*. (2012) showed that the highest mucilage yield of medicinal plant of *Plantago psyllium* respectively with 931 and 166 kg/ha mucilage was obtained with application mycorrhizal. Motahari *et al*. (2012) found that the yield of the active ingredients of calendula medicinal plants was obtained in the effect of consumption of

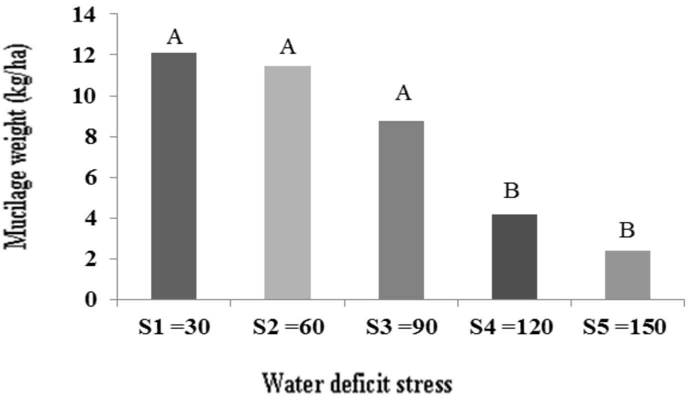

Figure 19. The main effect of water deficit stress on flower mucilage weight

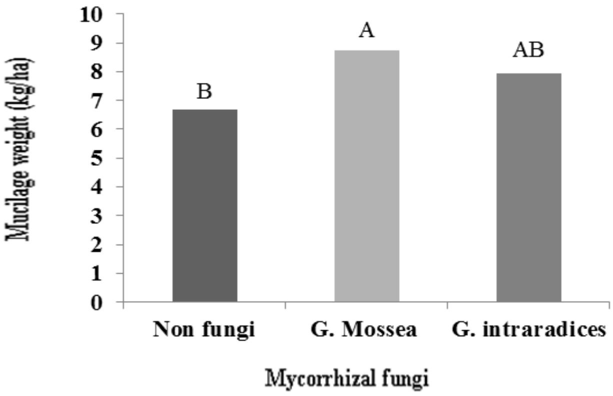

Figure 20. The main effect of mycorrhizal fungi on flower mucilage weight

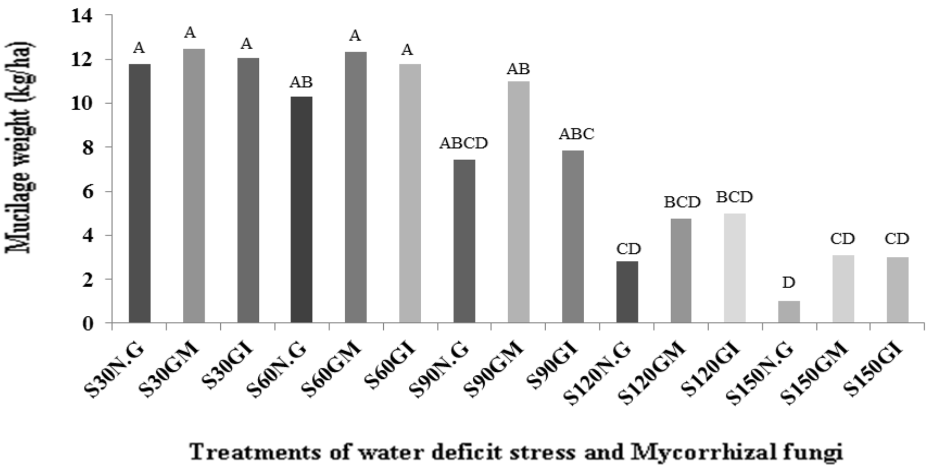

Figure 21. The interaction of water deficit stress and mycorrhizal fungi on flower mucilage weight

mycorrhizal *Glomus fasciculatum*. Ghasmi Syani *et al*. (2012) showed that the effect of irrigation intervals on the percentage of *Plantago psyllium* mucilage was significant. The highest percentage of *Plantago psyllium* mucilage was obtained with irrigation 7 and 14 days respectively.

Conclusion

The results of this study showed that water stress had significant effect on all studied characteristics of the borage plant and caused marked changes in them and with increasing water stress from 30 mm to 150 mm evaporation of evaporation pan, decreased all the characters except the WUE, somewhat increased water stress by up to 90 mm evaporation of evaporation pan could increase WUE. The application of mycorrhizal fungi reduced the negative effects of water stress in this study and could increase flower yield, WUE, percentage and weight of flower mucilage of borage in this survey.

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