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EFFECT OF MYCORRHIZA AND P SOLUBLE BACTERIA ON YIELD AND ITS COMPONENTS OF MAIZE (*ZEA MAYS* L.) UNDER WATER STRESS CONDITION

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ABSTRACT

A field experiment was carried out in order to evaluate the effect of mycorrhiza and P soluble bacteria on yield and yield components of maize (*zea mays* L. cv. SC600) under water stress condition in the faculty of agronomy and plant breeding, Islamic Azad University, Boroujerd Branch, Iran during the growing seasons 2013-2014. The experiment was laid out in a split-plot arrangement based on randomized block design with three replications. Treatments were different irrigation periods (7, 14 and 21 days) in main plots and in sub plots were stand (mycorrhiza strain of *Glomus intraradices*, phosphate barvar$_2$ and mycorrhiza+phosphate barvar$_2$*)* with control. Results showed that, the effect of water stress, mycorrhiza and P soluble bacteria on all traits were significant. However, the interaction effect of water stress mycorrhiza and P soluble bacteria on all traits were significant excepting SPAD and biomass. The simple comparison of the mean values showed that 7 days irrigation period treatment had the highest chlorophyll SPAD and bimass and 21 days irrigation period treatment had the lowest of them. However, Combined application of mycorrhiza and P soluble bacteria had the highest chlorophyll SPAD and bimass and control treatment had the lowest. Moreover, combined application of mycorrhiza and P soluble bacteria in 7 days irrigation period treatment had the highest number of row per cob, number of grain per cob, 100 grain weight, grain yield and harvest index but 21 day irrigation period without application of mycorrhiza and P soluble bacteria had the lowest of them. It can be stated that with respect to the alleviating effects of mycorrhiza fungi under water stress on corn grain yield, these fungi can enhance corn water efficiency under drought conditions and hence increase corn yield. Moreover, positive effect of mycorrhiza and P soluble bacteria is due to increasing of maize plant tolerance to water stress. We can increase yield and yield components of maize by decrease of irrigation period and application mycorrhiza and P soluble bacteria.

Key words: Mycorrhiza, P soluble bacteria and yield components

INTRODUCTION

Drought is one of the most important stresses affecting plant growth and production (Cheong et al. 2003). Drought stress is deleterious for plant growth, yield and mineral nutrition (Samarah et al., 2004). Drought stress causes damage to cell membrane and photosynthetic system. Moreover, plant root and shoot are damaged by drought stress, decreasing leaf surface area (Hopkins and Huner 2004). The studies of researchers have indicated that, lack of organic materials and existence of alkali reaction in calcareous soils can lead to lack of micronutrients in these soils (Auge, 2001). Soil moisture status during the reproductive phase of crops plays an important role to determine the impact of yield component in final grain yield (Singh and Bhushan, 1980). Biglouei et al (2007) reported that the increase of drought stress in K.S.C.704 corn, led to increase of grain yield and protein percentage. They also declared that grain protein in irrigation treatments after 50, 75 and 100 percent water depletion, were relatively 5.8, 7.2 and 7.4. Corn cellular development decreases under different drought stress levels, which eventually reduces plant growth and production (Laffitte and Edmeades 1995). Water stress can decrease number and shape of root hairs (Worral & Roughley, 1976), and when nodules are formed, drought alters nodule structure and weight, nitrogenase activity, and synthases of: sucrose, glutamate and glutamine (Ramos et al., 1999) that in results laid to the reduction in yield of soybeans. Water loss in the plant tissue will decrease cell turgor, increasing the concentration of macro-molecules and water chemical compounds in plants (Mubiyanto, 1997). Drought stress causes plants shortened, suppressing the development of soybean root and shoot (Soepandi et al, 1997) that laid to the reduction of biomass yield, accelerate flowering and harvest (Yusuf et al, 1993).

The most accepted mechanism for increasing drought stress by mycorrhiza in plants is osmotic adjustment which allowes cells to maintain turger and the processes that depend on it, such as cellular expansion and growth, stomatal opening and photosynthesis, as well as keeping a gradient of water potential favourable to water entrance into the plant (Ague, 2001). Mycorrhizal plants, however had significantly higher grain and biomass dry weights than non-mycorrhizal ones at all moisture levels except for grain weight at FC. Regardless of moisture treatments, bacterial inoculation caused a significant enhancemet in grain weight. The reduction in grain yield under water stress treatments may be attributed to the limitation of dry matter partitioning to the reproductive sink or even grain formation factors as has been reported by Turk et al (1980). Mycorrhizal fungi increase plant growth without damaging the environment (Moallem and Eshghizadeh, 2007). This fungus symbiosis with plant roots, thereby increasing the contact area with the ground, through the development of fungal hyphae that subsequently act as water and nutrient uptake efficiency of nitrogen, phosphorus, potassium, calcium, magnesium, zinc and copper increase to (Smith and Read, 1997).

Mycorrhiza enhances plant growth through the ability of extrarradical fungal hyphae to take up low-diffusing nutrients such as P from soil (Varma & Hock, 1998). The importance of AM symbiosis in legume plants has been traditionally attributed to the high P requirements of nodulation and N2 fixation processes (Barea & Azcón-Aguilar, 1983).

Therefore this study was planned to examine effect of mycorrhiza and P soluble bacteria on yield and yield components of maize (*zea mays* L.) under water stress condition.

MATERIALS AND METHODS

This experiment was carried out in order to evaluate the effect of mycorrhiza and P soluble bacteria on yield and yield components of maize (*zea mays* L.) SC600 cultivar under water stress condition in the faculty of agronomy and plant breeding, Islamic Azad University, Boroujerd Branch (experiment station: Hamedan), Iran during the growing seasons 2013- 2014. Soil property of experimental field showed in table1.

Table 1: Soil property of experiment site

soil Texture	sand (%)	Silt (%)	Clay (%)	K (mg/kg)	P (ppm)	N (%)	pH	EC (ds/m)	Depth
LC	20	45	35	220	8.2	0.1	7.7	0.409	0-30

The experiment was laid out in a split-plot arrangement based on randomized block design with three replications. Treatments were different irrigation periods (7, 14 and 21 days) in main plots and in sub plots were stand (mycorrhiza strain of *Glomus intraradices*, phosphate barvar$_2$ and mycorrhiza+phosphate barvar$_2$) with control.

In this field experiment there were 6 rows in each plot and rows were 6 m long with 0.75 m row spacing and plant to plant spacing was 18 cm too. At maturity, two outer rows for each plot, 50 cm from each end of the plots, were left as borders and the middle 3m^2 of the four central rows were harvested. After irrigation SPAD was recorded by manual chlorophyll meter. Then yield components were calculated as standard methods with using 8 plant. To determine grain yield and biomass yield, we removed and cleaned all the seeds produced within middle 3m^2 of the four central rows in each plot. Then grain yield and biomass yield recorded on a dry weight basis. Yield was defined in terms of grams per square meter and quintals per hectare. Replicated samples of clean seed (broken grain and foreign material removed) were sampled randomly and 1000-grain were counted and weighed. The harvest index was accounted with follow:

HI = (Economical yield / Biological yield)

The statistical analyses to determine the individual and interactive effects of treatments were conducted using JMP 5.0.1.2 (SAS Institute Inc., 2002). Statistical significance was declared at $P \leq 0.05$ and $P \leq 0.01$. Treatment effects from the two runs of experiments followed a similar trend, and thus the data from the two independent runs were combined in the analysis.

RESULTS AND DISCUSSION

Chlorophyll SPAD: Based on the results of the analysis of variance, the effect of water stress and application of mycorrhiza and P soluble fertilizer on chlorophyll content (SPAD) were significant only (table 2). The comparison of the mean values of the chlorophyll content for water stress showed that 7 day irrigation period treatment had the highest (49) chlorophyll content and 21 day irrigation period treatment had the lowest (36) chlorophyll content (figure 1). The comparison of the mean values of the chlorophyll content for application of mycorrhiza and P soluble fertilizer showed that combined application of application of mycorrhiza and P soluble fertilizer had the highest (48) chlorophyll content and non application of mycorrhiza and P soluble fertilizer had the lowest (39) chlorophyll content (figure 2).

Number of row per cob: The effect of water stress and application of mycorrhiza and P soluble fertilizer and interaction between them on number of row per cob were significant (table 2). The comparison of the mean values of the number of row per cob showed that 7 day irrigation period treatment with use of mycorrhiza and P soluble fertilizer had the highest (16) and 21 day irrigation period treatment without mycorrhiza and P soluble fertilizer had the lowest (10.5) number of row per cob measurement (figure 3).

Number of grain per cob: The results showed that, the effect of water stress, mycorrhiza and P soluble fertilizer and interaction between them on number of grain per cob were significant (table 2). The comparison of the mean values of the number of grain per cob for interaction between water stress and mycorrhiza and P soluble fertilizer showed that 7 day irrigation period treatment with use of mycorrhiza and P soluble fertilizer had the highest (585) number of grain per cob and 21 day irrigation period treatment without use of mycorrhiza and P soluble fertilizer had the lowest (255) number of grain per cob (figure 4).

100 grain weight: Based on the results of the analysis of variance the effect of water stress, mycorrhiza and P soluble fertilizer treatment and interaction between them were significant on 100 grain weight (table 2). The comparison of the mean values of the 100-grain weight showed that 7 day irrigation period treatment with use of mycorrhiza and P soluble fertilizer had the highest (27g) and 21 day irrigation period treatment without mycorrhiza and P soluble fertilizer had the lowest (15.5g) 100-grain weight (figure 5).

Biomass yield: The results showed that the effect of water stress and mycorrhiza and P soluble fertilizer on biomass yield were significant (table 2). The comparison of the mean values of the biomass yield for water stress showed that 7 day irrigation period treatment had the highest (19 ton/ha) biomass yield and 21 day irrigation period treatment had the lowest (9.8 ton/ha) biomass yield (figure 6). The comparison of the mean values of the biomass yield for application of mycorrhiza and P soluble fertilizer showed that combined application of application of mycorrhiza and P soluble fertilizer had the highest (17 ton/ha) biomass yield and non application of mycorrhiza and P soluble fertilizer had the lowest (11 ton/ha) biomass yield (figure 7).

Grain yield: The results showed that the effect of water stress, mycorrhiza and P soluble fertilizer and interaction between them on grain yield were significant (table 2). The comparison of the mean values of the grain yield for interaction between water stress and mycorrhiza and P soluble fertilizer showed that 7day irrigation period treatment with use of mycorrhiza and P soluble fertilizer had the highest (12.1 ton/ha) grain yield and non application of mycorrhiza and P soluble fertilizer in 21 day irrigation period treatment had the lowest (2 ton/ha) grain yield (figure 8).

Harvest index (HI): Based on the results of the analysis of variance, the effect of water stress, mycorrhiza and P soluble fertilizer and interaction between them on harvest index were significant (table 2). The comparison of the mean values of the harvest index for interaction between water stress and mycorrhiza and P soluble fertilizer showed that 7day irrigation period treatment with use of mycorrhiza and P soluble fertilizer had the highest (53%) harvest index and application of mycorrhiza in 21 day irrigation period treatment had the lowest (19%) harvest index (figure 9).

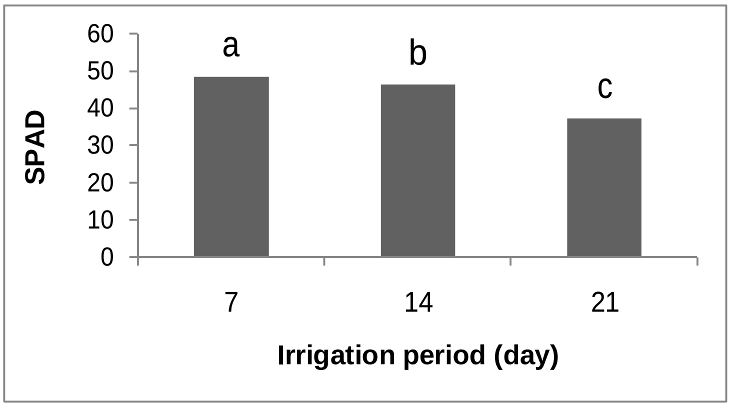

Figure 1: Effect of water stress on chlorophyll SPAD in maize.
Means by the uncommon letter in each column are significantly different ($p<0.05$)

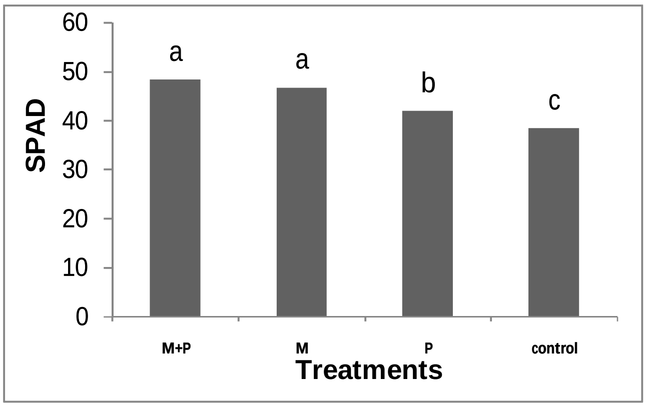

Figure 2: Effect of mycorrhiza and P soluble bacteria on chlorophyll SPAD in maize.
Means by the uncommon letter in each column are significantly different ($p<0.05$)
(M=mycorrhiza, P=phosphate barvar$_2$)

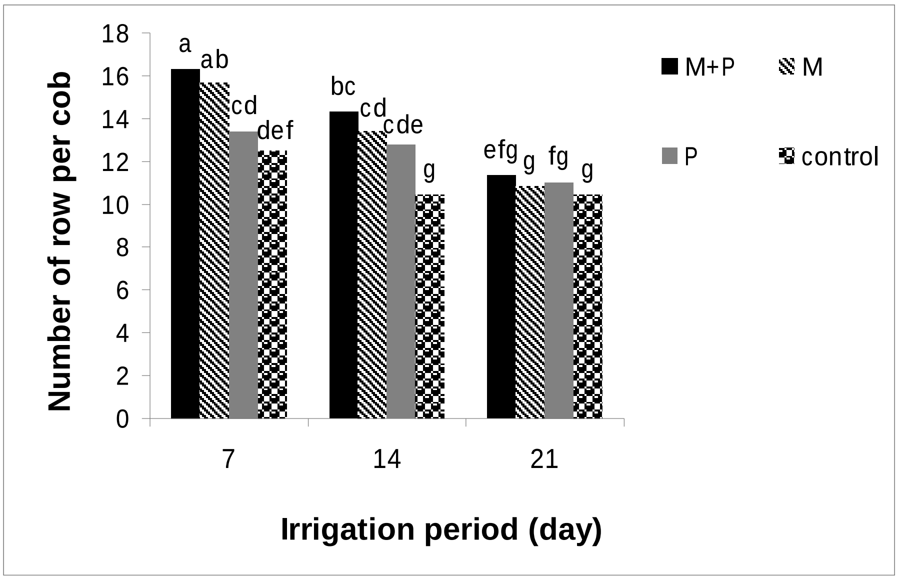

Figure 3: Effect of water stress, mycorrhiza and P soluble bacteria on number of row per cob in maize.
Means by the uncommon letter in each column are significantly different (p<0.05)
(M=mycorrhiza, P=phosphate barvar$_2$)

Table 2: Analysis of variance for yield, yield components of maize under water stress, mycorrhiza and P soluble bacteria

treatments	df	SPAD	number of row per cob	number of grain per cob	100 grain weight	biomass yield	grain yield	harvest index
R	2	4.7	2.9	2026	0.61	4.2	0.17	11.1
Water stress (A)	2	419**	37**	152558**	301**	262**	139.3**	1581**
Ea	4	10.5	1.8	744	2.2	3.2	0.56	87
Mycorrhiza+ P soluble bacteria (B)	3	182**	13.8**	17667**	40.8**	55**	26.1**	239.2**
A*B	6	10.5	2.3*	1992*	5.5**	0.53	3.87**	102.9**
Eb	18	5.7	0.77	548	1.3	0.48	0.34	14.9
CV(%)		5.4	6.9	5.47	6.09	4.78	10.97	11.4

ns: Non-significant, * and **: Significant at 5% and 1% probability levels, respectively

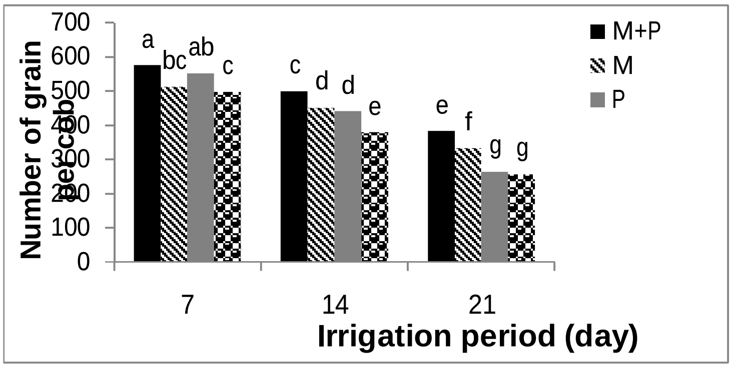

Figure 4: Effect of water stress, mycorrhiza and P soluble bacteria on number of grain per cob in maize.
Means by the uncommon letter in each column are significantly different (p<0.05)
(M=mycorrhiza, P=phosphate barvar2)

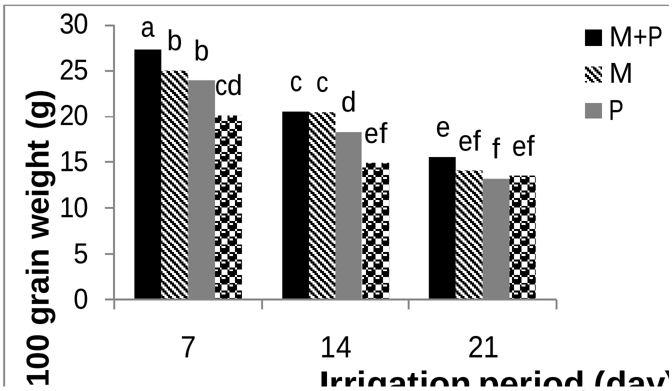

Figure 5: Effect of water stress, mycorrhiza and P soluble bacteria on number of 100 grain weight of maize.
Means by the uncommon letter in each column are significantly different (p<0.05)
(M=mycorrhiza, P=phosphate barvar$_2$)

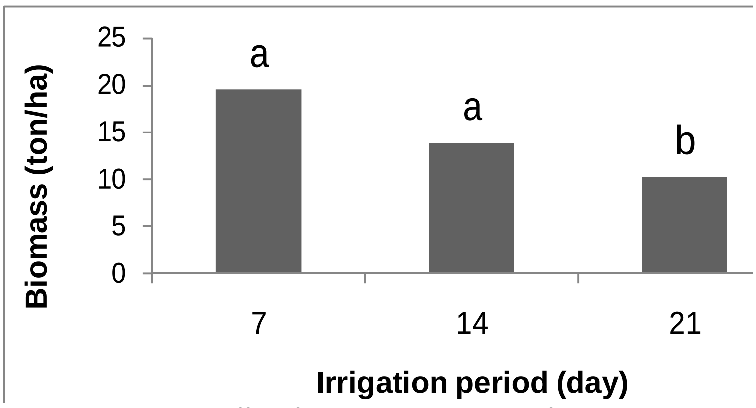

Figure 6: Effect of water stress on biomass of maize.
Means by the uncommon letter in each column are significantly different (p<0.05)

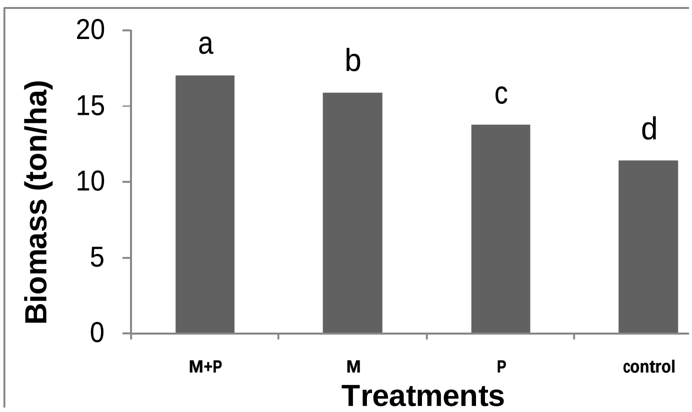

Figure 7: Effect of mycorrhiza and P soluble bacteria on biomass of maize.
Means by the uncommon letter in each column are significantly different (p<0.05)
(M=mycorrhiza, P=phosphate barvar$_2$)

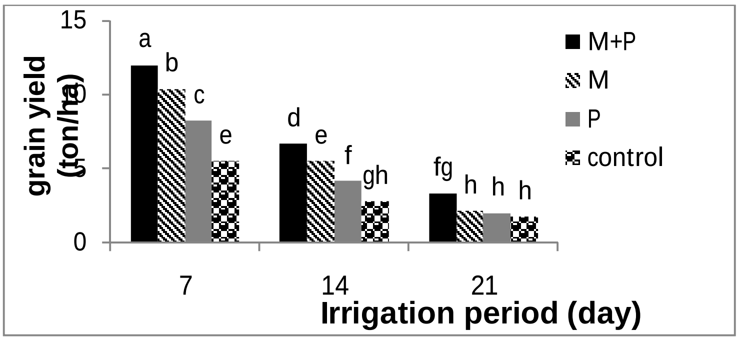

Figure 8: Effect of water stress, mycorrhiza and P soluble bacteria on grain yield of maize. Means by the uncommon letter in each column are significantly different (p<0.05) (M=mycorrhiza, P=phosphate barvar$_2$)

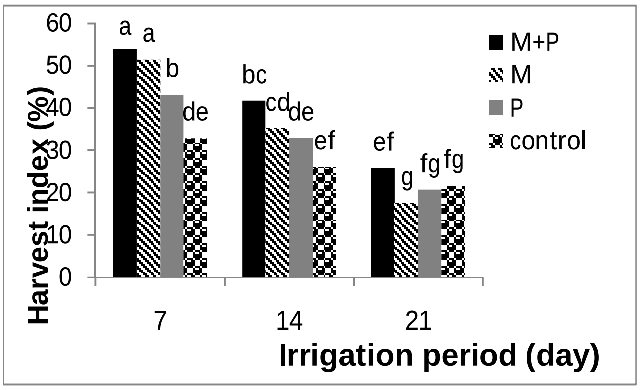

Figure 9: Effect of water stress, mycorrhiza and P soluble bacteria on grain yield of maize. Means by the uncommon letter in each column are significantly different (p<0.05) (M=mycorrhiza, P=phosphate barvar$_2$)

Results of the present study showed that, the effect of water stress, mycorrhiza and P soluble bacteria on all traits were significant. However, the interaction effect of water stress mycorrhiza and P soluble bacteria on all traits were significant excepting SPAD and biomass. Other researchers showed that between the treated and non-use of mycorrhizal fertilizer, the yield difference was significant, so that the highest grain yield was obtained in mycorrhizal fertilizer (Alizadeh and Alizadeh, 2008). In the present study results showed that, 7 days irrigation period and combined application of mycorrhiza and P soluble bacteria had the highest chlorophyll contents (SPAD) (figure 1 and 2). However 21 days irrigation period in all fertilizer treatments had the lowest SPAD. Mycorrhizal fertilizer significantly increased chlorophyll contents, grain number per row, number of grains per cob, cob weight and grain yield of corn (Sajedi and Madani, 2008). Mycorrhiza and P soluble bacteria increased total chlorophyll contents as compared with the control that was perhaps due to the association with chlorophyll formation (Mazaherinia et al., 2010).

Soil moisture status during the reproductive phase of crops plays an important role to determine the impact of yield component in final grain yield (Singh and Bhushan, 1980). In the present study water stress in 21 day irrigation period decreased number of row per cob, number of grain per cob and 100 grain weight but application of mycorrhiza and P soluble bacteria increased them. The number of grain per cob in 7 day irrigation period giving over the 21 day irrigation period. However, the results showed that under 7 day irrigation period conditions and application of mycorrhiza and P soluble bacteria significantly gave better grain yields than 21 day irrigation period conditions. However the reslts showed that mycorrhiza and P soluble bacteria increased plant tolerance to water stress that with application of them yield and yield components of maize were increased significantly. The most accepted mechanism for increasing drought stress by mycorrhiza in plants is osmotic adjustment which allowes cells to maintain turger and the processes that depend on it, such as cellular expansion and growth, stomatal opening and photosynthesis, as well as keeping a gradient of water potential favourable to water entrance into the plant (Ague, 2001). Mycorrhizal plants, however had significantly higher grain and biomass dry weights than non-mycorrhizal ones at all moisture levels except for grain weight at FC. Regardless of moisture treatments, bacterial inoculation caused a significant enhancemet in grain weight. The reduction in grain yield under water stress treatments may be attributed to the limitation of dry matter partitioning to the reproductive sink or even grain formation factors as has been reported by Turk et al (1980). Water stress can decrease number and shape of root hairs (Worral & Roughley, 1976), and when nodules are formed, drought alters nodule structure and weight, nitrogenase activity, and synthases of: sucrose, glutamate and glutamine (Ramos et al., 1999) that in results laid to the reduction in yield of soybeans. Water stress significantly decreased corn yield and its components. Similar to the mycorrhiza treatment and application of P soluble bacteria also numerically increased corn yield and its components. Drought stress causes plants shortened, suppressing the development of soybean root and shoot (Soepandi et al, 1997) that laid to the reduction of biomass yield, accelerate flowering and harvest (Yusuf et al, 1993). The combined effect of mycorrhiza and P soluble bacteria in 7 day irrigation period numerically increased corn grain yield, relative to the 21 day irrigation period and non application of mycorrhiza and

P soluble bacteria. Many researches on the effects of this symbiosis on physiological aspects of plants have shown that, mycorrhiza increases uptake of Mn, Ca, Mg, K, S, P, N and Fe. This symbiosis about uptake of phosphorus and immovable nutrients in the stress conditions is very significant (Li-Lin et al., 1991). Tabatabaei and Ranjbar, (2005) in an experiment on the Nutrifeed Millet, reported that, yield decreased with increasing drought stress levels. Application of mycorrhiza and Zn chelate had a positive effect on the grain yield, biomass yield and harvest index of maize. Ziska and Hall (1983) founded that the effect of water stress on HI to the reduction in assimilate supply attributed. In maize, the final grain yield is dependent on the number of cob per plant, number of grains per cob and the extent to which grains are filled. During seed development, assimilate transported from leaves to seeds was decreased. Other influences of water stress resulting assimilate movement speed decrease that lead to the reduction of grain yield. Water loss in the plant tissue will decrease cell turgor, increasing the concentration of macro-molecules and water chemical compounds in plants (Mubiyanto, 1997). Arab et al (2013) in millet founded that, application of *Glomus fasiculatum* in 6 days of irrigation, significantly increased harvest index of panicle in plant. Moreover, no application of bio-fertilizers in 18 day of irrigation, resulted in lower levels of panicle per plant and harvest index. They told that application of *Glomus mosseae* and *Glomus intaradices* fertilizers in each level of irrigation increased grain yield relative to the control (no fertilizer), but there was no significant differences in yield between fertilizers. This means that the application of *Glomus fasiculatum* fertilizer has had the greatest effect on grain yield of Millet. Symbiotic mycorrhizal fungi with most plants under drought stress conditions, improve the productivity of plants to absorb more immovable nutrients such as phosphorus, zinc and copper (Auge, 2001). Kiyatno (1993) stated that water stress will reduce number of roots, plant height, plant dry weight, number of pods and weight of 100 seeds. Other researchers Sariyah (1992) stated that increasing water stress will decrease of leaf water potential, relative growth rate, dry seed weight, plant height, number of pods and seed yield per plant. Mycorrhiza have reportedly increased nutrient uptake, salinity tolerance, drought tolerance, water uptake, root disease resistance, and photosynthesis (Sharma, 1994). Positive effects of mycorrhiza on plants include increases in height (Safapour, 2011), biomass (Ramana, 2010), shoot: root ratio (Veresoglou, 2012), production of flowers (Carey, 1992), and yield in crop plants such as Glycine max. In final the present study concluded that maximum production of maize yield and yield components was recorded for both application of mycorrhiza and P soluble bacteria in 7 day irrigation period treatment. It can be stated that with respect to the alleviating effects of mycorrhiza fungi under water stress on corn grain yield, these fungi can enhance corn water efficiency under drought conditions and hence increase corn yield. Moreover, positive effect of mycorrhiza and P soluble bacteria is due to increasing of plant tolerance to water stress.

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