Efficiency of Microbial Inoculants on Yield and Yield Components of Mung Bean (*Vigna Radiata* L. Wilczek var. *Parto*) in Drought Stressed Conditions

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ABSTRACT

Tolerance of plants to drought stress is a complex biological phenomenon, which manipulated by several physiological and morphological factors, and it is growth stage specific. So far, little efforts have been made simultaneously to characterize the advantages of fungi and bacteria interactions to improve productivity of mung bean in imposed drought stress through the different growth stages. In this study, yield and yield components of mung bean (*Vigna radiata* L. Wilczek var. *Parto*) evaluated by soil microbial inoculums in drought−stressed conditions, by a split plot Randomized Completely Block Design (RCBD) with three replications in Miyaneh, Iran, during 2016. The main plots allocated to three levels of drought stress included: normal irrigation (control), stopping irrigation in flowering stage, stopping irrigation in pods formation stage. Sub−plots considered to four treatments of inoculations included: non−inoculation (control), inoculation with *Glomus mosseae*, *Pseudomonas fluorescens* strain 169 and *Glomus mosseae* + *Pseudomonas fluorescens* strain 169. Drought stress decreased the number of seeds per pod, pods diameter, the number of pods per plant, biomass and yield in comparison with normal irrigation. The reduction of yield cutting irrigation in pod formation stage was more than flowering stage. Inoculation with combination of *Glomus mosseae* and *Pseudomonas fluorescens* strain 169 enhanced the number of seeds per pod, pods length and pods diameter. *Glomus mosseae* inoculation was more efficient to increase the number of seeds per plant, dry weight of pods, biomass and yield. The effectiveness of *Pseudomonas fluorescens* strain 169 was observed in producing high harvest index. The most positive effects of *Glomus mosseae* inoculation on alleviation of drought stress was through increasing the number of seeds per pod, dry weight of pods, biomass and yield. *Glomus mosseae* and *Pseudomonas fluorescence* 169 in pod filling stages under drought condition increased external hyphae network.

Keywords: Drought stress, *glomus mosseae*, *pseudomonas fluorescens* strain 169, yield, mung bean (*Vigna radiata* L. Wilczek)

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INTRODUCTION

Arbuscular mycorrizal fungi currently were placed in the phylum Glomeromycota and divided in four orders, eleven families, twenty−five genus and more than two hundred species (Souza, 2015). These microorganisms have a main role in management of drought stress condition. The unique characteristics in tolerance of environmental stresses, potential to live in different conditions and genetically diversity of them have been recognized. Some methods for suitable usage of microorganisms described to produce crop products. These microorganisms are excellent models to distinguish active mechanism in dry land area, which are fruitful in engineering to produce agricultural products (Ansari *et al*., 2015). Rezvani moghaddam *et al*. (2015) reported that by means of agricultural inputs such as biofertilizers and mycorrhizae which increase the growth of upper ground parts of plants, economical yield will be improving. They described that in order to have high yield, widely application of inputs involve in agriculture, having plants free from chemical remains is necessary and fundamental in producing, processing and distributing of products. Therefore, it seems that even though the yield of plants results from application of mycorrhizae and biofertilizers in comparison with using chemical fertilizers is less or equal, but application of biological fertilizers is a best way to produce healthy plants. Some bacteria living in soil can induce mycorrhizae symbiosis of plants. However, the exact mechanisms of bacteria increasing drought resistance of plants have never been discovered accurately. Frey−Klett *et al*. (1997) described that induction of mycorrhizae growth by bacteria occurs before symbiosis with plants (Garbaye and Bowen, 1987; Founoune *et al*., 2002). Founoune *et al*. (2002) displayed that bacteria can fortify distinguished mechanisms in both symbionts. Some researchers reported the synergistic effects of mycorrhizae and rhizobacteria inoculation (Xavier and Germida, 2002). Mycorrhizae and rhizobium symbiosis is necessary for legumes. In drought stressed condition, mycorrhizae and bacteria are able to have synergistic interaction, which increase the germination and growth of fungi (Carpenter− Boggs *et al*., 1995) and by increasing the permeability of root cells can improve water and nutrient absorbing of plants. Roesti *et al*. (2006) reported that the effects of mycorrhizae and phosphorous solubilizing bacteria and inoculation of wheat (*Triticum aestivum*) growth characteristics is positive. Colonization of mycorrhizae supplementary bacteria such as Pseudomonas by attaching to root improved the mycorrhizae fungi, plant symbiosis, and has more benefits for host plant (Schalamuk *et al*., 2006). But, Bahadori *et al*. (2013) reported that application of *G. mosseae* and *P. fluorescence* at the same time showed antagonistic effects and reduced nutrient absorption and dry yield of plant in comparison with other treatments. Rillig *et al*. (2005) reported that bacteria helper mycorrhizae are specialized for each fungi, but this is not specialized for plants. Some investigations displayed that only few number of bacteria strains have bilateral positive and synergistic effect with mycorrhizae fungi (Ruiz−Lozano and Bonfante, 2000). In Cytoplasm of mycorrhizae fungi, there is a pseudo−bacteria structure, which bring about synergistic effects and associate with fungi and it is a specific bacterium (Artursson *et al*., 2006). The inoculation of green gram (*Vigna radiata* L. Wilczk) with rhizobium and mycorrhizae fungi increased dry weight of root and the number of nodules in plant roots. Mechanisms in which *Pseudomonas fluorescence* may affect AM fungi and their host plant mentioned as (1) effects on the receptivity of root (2) effects on the root−fungus recognition (3) effects on the fungal growth (4) modification of the chemistry of rhizospheric soil and (5) effects on the germination of the fungal propagules (Garbaye, 1994). Farnia and Hadadi (2015) suggested that with respect to the alleviating effects of mycorrhizal fungi under water stress on corn grain yield, these fungi can enhance corn water use efficiency under drought conditions and increase corn yield. The ability of these fungi and bacteria differ in increasing drought tolerance of plants based on their strain, soil structure and climate condition. Based on variety of plants, there are different adaptations to fungi and bacteria strains. Therefore, awareness about the best symbiotic of fungi and bacteria for each variety of plant makes it possible to recommend the best symbiotic of plant to have high yield and resistance in drought condition. The mechanism of *Pseudomonas fluorescence* 169 associated with *Glomus mosseae* increasing drought resistance of plants included producing mycelium growth induced substances, germination of fungi spores and establishment of them in root and alleviation of environmental stresses. Another point which is worth to mention is about drought stress effects on different plant growth stages. For instance, flowering and pod formation stages both are critical growth stages of every plant. Supplement irrigation, particularly at the pod filling stage, improves final yield that results an increment in yield component (Ghanbari and Mollashahi Javan, 2015). Drought stresses in these two growth stages of plants, mentioned have different influences on yield of plant. Ghanbari and Mollashahi Javan (2015) announced that although mung bean defined as a tolerant plant to drought, all aspects of growth and development in its genotypes have been influenced by water deficit, containing pod number, 100 seeds weight, economic yield, biological yield, pods length. The aim of this work was to evaluate the effects of drought stress in flowering and pod formation stages of mung bean in comparison with normal irrigation and the role of *G. mosseae* and *Pseudomonas fluorescence* symbiosis protecting mung bean to produce high seed yield in drought stress condition in Miyaneh county of Iran.

MATERIALS AND METHODS

The experiment was conducted in research farm of Miyaneh Branch, Islamic Azad University, Iran (37º, 55´N; 47º, 11´ W; elevation 1, 100 m.) during 2016 in Randomized Complete Block Design based on split plot with three replications. Experimental plots were drought stress including: normal irrigation (control), stopping irrigation in flowering stage, stopping irrigation in pod setting stage. Inoculations as second factor with four levels were included non−inoculation (Control), inoculation with *Glomus mosseae*, inoculation of *Pseudomonas fluorescens* strain 169 and inoculation by *Glomus mosseae* + *Pseudomonas fluorescens* strain 169.

Parto variety of mung bean (*Vigna radiata* L. Wilczek) which used in this study provided from Seed and Plant improvement Institute, Karaj, Iran. Suspension solution of *Pseudomonas fluorescens* strain 169 with 10^8−10^9 live and active bacteria per ml ($CFUml^{-1}$) were provided from Water and Soil Research Institute, Karaj, Iran. *Glomus mosseae* was provided from Zist Fanavaraneh Turan Company, which had approximately 30 live fungi per gram and produced by culturing in host plant, which used in form of soil mixed spores and hyphae. Charoonnart *et al*. (2015) suggested that addition of 50 spores of *G. mosseae* per plant was the best condition which improves plant growth. Inoculation of seeds by *Pseudomonas fluorescence* 169 done in the morning by mixing them in an aluminum paper. The 2% glucose solution was added to increase the number of bacteria attached to seeds and allowed them to dry in shadow. To increase the efficiency of fungi and bacteria in sowing time, seeds were never sterilized.

Seeds were sown in 6 rows, 3 × 1.5 m^2, with 50 cm inter−row spacing. Each plot was separated by having an extra row on both sides to protect the contamination of the microbial inoculants in soil. All agricultural practices such as agronomic operations and irrigation methods regularly were done according to agriculture department guideline of Miyaneh Branch, Islamic Azad University. During the experiment, substances as sufficient amount of fertilizer were applied. As Table 1 shows, based on physicochemical analysis, soil structure components including clay and some amount of organic carbon, nitrogen, phosphorous and potassium in experimental farm were 1.5%, 0.1%, 5.70 ($mg.kg^{-1}$) and 301($mg.kg^{-1}$), respectively.

For data collection, yield components were recorded according to sampling of 5 plants per plot. Yield components were the number of seeds per pod, pods length (cm), pods diameter (mm), the number of pods per plant, the number of seeds per plant, dry weight of pods (gram) and, 100 seeds weight (gram). Biological and seed yield were calculated from central rows after removing margin lines and then converted to kg per hectare. Harvest index were calculated with equation (1):

$$HI = \frac{SY}{BY} \times 100 \qquad \text{Equation (1)}$$

HI: Harvest Index
SY: Seed Yield
BY: Biomass Yield

Mycorrhizal dependency (%) and mycorrhizae growth (%) were estimated with equations (2 and 3):

Mycorrhizal response = (seed weight of mycorrhizal plant−seed weight of non−mycorrhizal plant)/seed weight of non−mycorrhizal plant × 100 Equation (2)

Mycorrhizal dependency (%) = (seed weight of mycorrhizal plant−seed weight of non−mycorrhizal plant)/seed weight of non−mycorrhizal plant × 100 Equation (3)

Figure 1 Experimental plots of mung bean (*Vigna radiate* L. Wilczek) in Miyaneh Branch, Islamic Azad University

Table 1 Soil characteristics of the experimental station

Clay (%)	Silt (%)	Sand (%)	Soil structure	OC (%)	N (%)	P ($mg.kg^{-1}$)	K ($mg.kg^{-1}$)
48	29	23	Clay	1.5	0.1	5.70	301

Statistical Analysis

All collected data have been analyzed for simple analysis of variance (ANOVA) using MSTAT−C software. Mean comparison done by SPSS (Ver.16) and was compared by Duncan test at 5% probability level (Nouri *et al*., 2007).

RESULTS AND DISCUSSION

The Number of the Seeds per Pod

The results of variance analysis table showed that effects of stress, inoculations and interactions between them based on the number of seeds per pod were significant ($P < 0.01$). Inoculations of Mung bean (*Vigna radiata* L. Wilczek) with *Pseudomonas fluorescence* 169 and *Glomus mosseae* increased the number of seeds per pod in comparison with control (Table 2). It seems that *Pseudomonas fluorescence* 169 which is similar to other plant growth promoting bacteria, alters phytohormon levels and thereby affects plant hormonal balance and it's response to stress.

According to Table 3, it seems that *Pseudomonas fluorescence* 169 as if other bacteria strains by over producing cytokinins especially during drought stress protect the plant from harm effects of drought. Also, *Pseudomonas fluorescence* 169 by solubilization and mineralization of phosphorus makes them available to support plant growth. Ji *et al*. (2011) reported that drought stress in reproductive stage causes pollen sterility and grain loss in wheat (*Triticum aestivum* L.).

100−Seeds Weight

As is shown in Table 2, there were no significant differences between all experimental factors based on 100−seeds weight. In addition, all treatments were placed in the same group regarding with their significance statistically. It seems that 100−seeds weight was more influenced by genetic controllers and less affected by environmental factors. Besides, Mirzaei *et al*. (2014) illustrated that environmental stresses such as drought cause an increase in remobilization of storage materials from secondary sources to the sink but it cannot compensate the reduction in amount of current photosynthesis, which produced due to lack of soil moisture.

Pods Length

As shown in Table 2, inoculations had significant effects on pods length of mung bean ($P < 0.01$). There were not differences among interaction of water stress treatments and inoculations, based on pods length. The combination inoculations of *Glomus mosseae* and *Pseudomonas fluorescens* 169 had the highest effect producing pods length with 8.036 cm. This value was insignificant with individually inoculation of *Glomus mosseae*. In addition, the synergistic affects between *Glomus mosseae* and *Pseudomonas fluorescens* strain 169 increasing pods length observed in table 3. The minimum value of pods length revealed in no−inoculation treatment with 6.571 cm. Togay *et al*. (2008) suggested that appropriate Rhizobium inoculation increases the number and length of chickpea pods in comparison with control.

Pods Diameter

Based on variance analysis table, there were significant differences among different stresses and type of inoculations, based on pod diameter ($P < 0.05$, $P < 0.01$) (Table 2). Means comparison showed that the highest average of pods diameter were produced in normal irrigation condition with 4.840 mm. Drought stresses in both flowering and pod formation stages significantly reduced pods diameter (Table 4). Pods formation stage was more vulnerable in lack of water condition. It seems that the decline in seed size because of drought stress imposed in pod formation stage is the main reason for this reduction. Synergistic effects of fungi and bacteria concluded on pods diameter. Inoculations with *Glomus mosseae* + *Pseudomonas fluorescens* strain 169 had the highest association to produce high pods diameter with average 4.618 mm., Nevertheless, with inoculation of *Glomus mosseae* was insignificant. The lowest pods diameter observed in no inoculation treatment (control) with 3.772 mm. (Table 4). It seems that competition for nutrients to derive energy−rich carbon compounds from host assimilates caused to mycorrhizosphere activate potential ability of *Glomus mosseae* and *Pseudomonas fluorescens* strain 169 to absorb more water, minerals, nutrients toward reproductive parts. Linderman and Paultiz (1990) reported that the synergistic effects between mycorrhizal and group of bacteria increased growth indexes in clover. The contribution of bacteria with mycorrhizal fungi by attaching to fungi spores and hyphae structures can extend rhizospheric surface.

The Number of the Pods per Plant

The results of variance analysis showed that the effect of drought stresses, inoculations and their interactions, based on the number of pods per plant were significant ($P < 0.05$, $P < 0.01$ and $P < 0.05$ respectively) (Table 2). Reduction in soil moisture accompany with high temperature in July (29ºC) and August (25.9ºC) affected on indeterminate growth characteristics of mung bean and consequentlydiminished pods number of plant. Mirzaei *et al*. (2014) suggested that reduction in amount of irrigation and the sudden increase in temperature would cause premature and aging of plants. It seems that microbial hyphae in soil provides an efficient pathway for nutrient/water up taking and transporting, allowing more efficient exploitation of water and nutrient reservoirs to be available for plant. Interactive effects between drought stress and inoculation showed that inoculation of *Glomus mosseae*, *Pseudomonas fluorescens* strain

169 and their interactions significantly increased the number of pods per plant under different irrigation regimes in comparison with no inoculation treatment (Figure 3). Rapparini and Peñuelas (2014) suggested that AM symbiosis increase the resistance of plants to drought through secondary actions such as improvement soil structural stability, which in turn increase the retention of soil water.

The Number of the Seeds per Plant

The seeds of plant were affected only by type of inoculation, which was significant ($P < 0.05$). As shown in Table 3, among different investigated inoculations, infection of mung bean by *Glomus mosseae* caused the maximum number of seeds per plant. In addition, the average number of seeds per plant in inoculation with *Glomus mosseae* was 118.895 (Table 3). It seems that *Glomus mosseae* inoculation increased nitrogenase activity in nodules, biomass, concentration of micronutrients, which caused high formation of seeds and nodules in mung bean (*Vigna radiata* L. Wilczek). Vejsadova *et al*. (1992) reported the same result in soybean inoculated with Bradyrhizobium and Japonicum.

Dry Weight of Pods

Dry weight of pods is a physiological trait which somewhat determines yield components of plant. Results showed that drought stress had significant effects on dry weight of pod ($P < 0.05$) (Table 2). In conclusion, dry weight of pods were more related to genetic. It seems that drought stress in pods formation stage caused the transportation of assimilates from leaves and stems to reproductive parts such as pods. This shipping of carbohydrates toward pods increased dry weight of pods under water deficit condition. The adaptation of *Glomus mosseae* with Parto variety of mung bean to make water, minerals and nutrients available for plant was remarkable and could be effective to increase dry weight of pods (6.852 gram). Beltrano and Ronco (2008) indicated that mycorrhizal symbiosis not only can increase plant growth and mineral uptaking but also induce drought resistance ability of plant. Based on Figure 4, the highest dry weight of pods distinguished in *Glomus mosseae* + normal irrigation treatment.

Biological Yield

Biological yield shows all dry matters of plant, and has significant role in high productivity. Results displayed significant differences among drought stress and inoculation treatments ($P < 0.01$). Their mutual performances were significant ($P < 0.05$) (Table 2). Molecular mechanisms activated by AM symbiosis to counteract drought include gene activation of functional proteins, such as the membrane transporter aquaporins and, potentially, ion and sugar transporters, in both roots and fungi. Improved nutrient/water uptake and transport in roots translates into enhanced hydration of aboveground organs that in turn affects physiological and biochemical processes. In addition, the ability of AM symbiosis to increase the drought resistance of plants through secondary actions such as the improvement of soil structural stability that in turn increases the retention of soil water reported by Rapparini and Peñuelas (2014). The mechanism predominantly used to explain the positive effect of *Pseudomonas fluorescence* 169 on plant growth, is its ability to produce auxin. In addition, about 80% of rhizosphere microbes can synthesize and release auxin as a secondary metabolite, which can increase vegetative growth and biological yield of plant. Previous studies approved the positive effects of fungi and bacteria alleviation drought stresses in plants (Reddy *et al*., 2002; Timmusk *et al*., 2014; Ortiz *et al*., 2015).

Table 2 Mean squares of seed yield and yield components of mung bean (*Vigna radiata* L. Wilczek var. *Parto*) under different inoculations and drought stress conditions

Source of variations	df	Mean squares				
		The number of seeds per pod	100 seeds Weight	Pods length	Pods diameter	The number of pods per plant
Rep.	2	0.716^{ns}	0.117^{ns}	0.331^{ns}	0.095^{ns}	16.365^{ns}
Stress	2	37.520**	0.124^{ns}	0.200^{ns}	5.924**	31.726*
Error(a)	4	0.138	0.220	1.427	0.066	2.613
Inoculation	3	37.919**	0.020^{ns}	5.572**	1.178*	23.463**
Inoculation × Stress	6	7.004**	0.257^{ns}	1.230^{ns}	0.439^{ns}	10.330*
Error(b)	18	0.369	0.068	0.686	0.297	2.594
CV%	−	7.890	6.980	11.400	12.890	22.940

Source of variations	df	Mean Squares				
		The number of seeds per plant	Dry weight of pods	Biological yield	Seed yield	Harvest index
Rep.	2	110.724^{ns}	1.464^{ns}	0.200^{ns}	22,379.296^{ns}	0.311^{ns}
Stress	2	783.126^{ns}	15.441*	0.384**	15,3634.482*	0.302^{ns}
Error(a)	4	664.267	4.569	0.015	20,971.941	0.038
Inoculation	3	3,549.614**	11.087*	0.740**	9,874.998**	0.475*
Inoculation× Stress	6	338.004^{ns}	11.702*	0.030*	27,119.541*	0.277^{ns}
Error(b)	18	677.660	3.469	0.008	9,225.184	0.155
Total	35					
CV%	−	28.200	32.570	6.400	25.320	14.100

Note: * significant at $P < 0.05$ level, ** significant at $P < 0.01$ level and ^{ns} non−significant

Table 3 Mean comparison of seed yield and yield components of mung bean (*Vigna radiata* (L.) Wilczek var. *Parto*) based on inoculations factor

Inoculation	Harvest index (%)	Pods length (cm)	Pods diameter (mm)	The number of pods per plant
No−inoculation	22.922[ab]	6.571[b]	3.772[b]	4.656[b]
Glomus mosseae	29.430[ab]	7.855[a]	4.378[a]	8.278[a]
Pseudomonas fluorescens 169	37.017[a]	6.607[b]	4.124[ab]	7.528[a]
G. mosseae+ *Pseudomonas fluorescens*169	21.489[b]	8.036[a]	4.618[a]	7.646[a]

Note: In each column means followed by same letter (s) have not significantly different at Duncan's (5%)

Table 4 Means comparison of seed yield and yield components of Mung bean (*Vigna radiata* L. Wilczek var. *Parto*) under drought stress condition

Drought stress	Pods diameter (mm)
Normal irrigation	4.840[a]
Stopping−irrigation in flowering stage	4.371[b]
Stopping−irrigation in pod setting stage	3.458[c]

Note: Means followed by same letter (s) are not significantly different at Duncan's (5%)

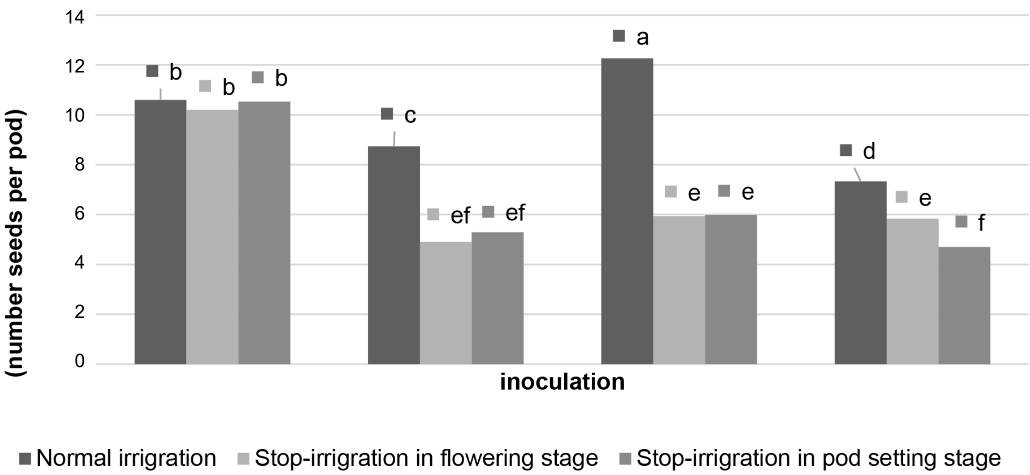

Figure 2 Interactions between drought stresses and inoculations on number of seeds per pod. Different letters indicating significant differences (P < 0.01)

Seed Yield and Harvest Index

Seed yield was affected by drought stress ($P < 0.05$) (Table 2). According to mean comparison, seed yield reduction observed in both stopping irrigation in flowering and pod formation stage treatments in comparison with normal irrigation (Table 4). Drought stress, due to restriction of water cause the embryos of some fertilized ovaries abort and plant produces few seeds (Salehi *et al*., 2008; Rannawake *et al*., 2011; Mirzaei *et al*., 2014). It seems that *Pseudomonase fluorescence* 169 like other strains of these bacteria improve symbiosis relationship between plant and Ectomycorrhizae by mechanism of inducing spores germination, mycelium growth, increasing the root−fungi connection with the ability of inducing tiny mycorrhizal roots production to reduce harm effects of drought stress on seed yield. Arshad *et al*. (2008) reported that some *Pseudomonase fluorescence* strains could promote ACC deaminase activity to help better tolerance of plant in drought condition. Drought stressed plants diverted significantly higher dry matter to roots and stems, while well−watered plants diverted to pods and grains (Kumar and Sharma, 2009). As shown in Figure 6, positive effect of *Glomus mosseae* on seeds yield and the role of these fungi inducing drought resistance of mung bean was more than other treatments. Based on data from harvest index, concluded that environmental conditions seldom effect on harvest index. Inoculations of *Pseudomonas fluorescens 169* had more influence on harvest index. In addition, the highest value of harvest index obtained in inoculation by *Pseudomonas fluorescens* strain 169 with 37.017 percent. The reason related to negative and high effect of these bacteria on biological yield, consequently leads to have high percentage of harvest index. Gholami and Mahmoudi (2015) found the effect of mycorrhizal on harvest index insignificant.

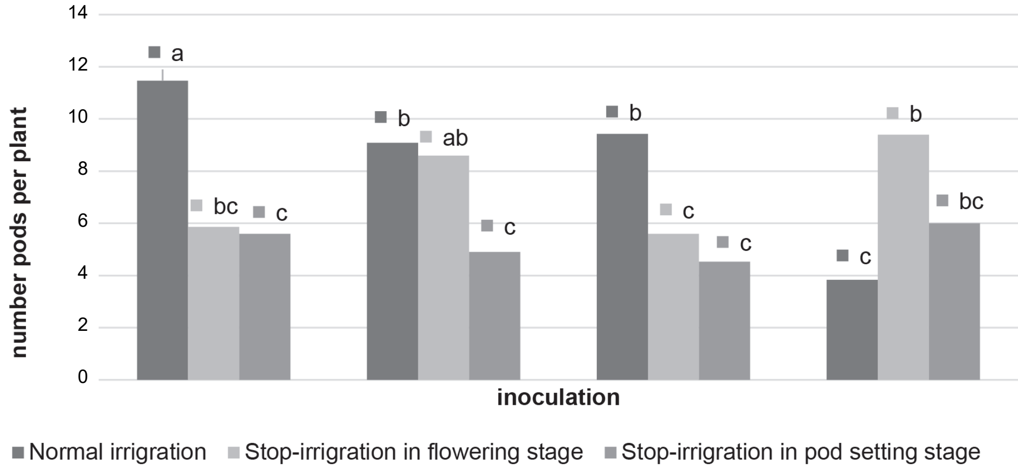

Figure 3 Interactive effects between drought stress and inoculations based on the number of pods per plant. Different letters indicating significant differences at $P < 0.01$

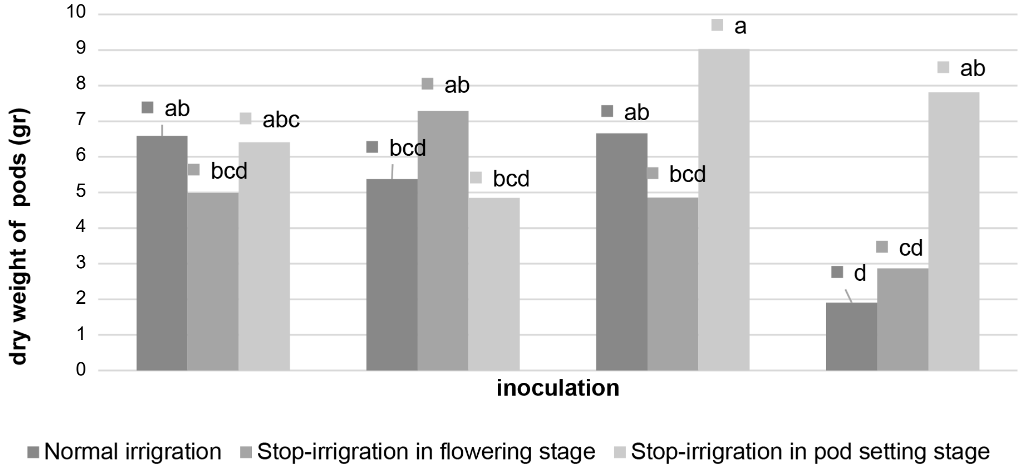

Figure 4 Interactive effects between drought stress and inoculations based on dry weight of pods. Different letters indicating significant differences at $P < 0.05$

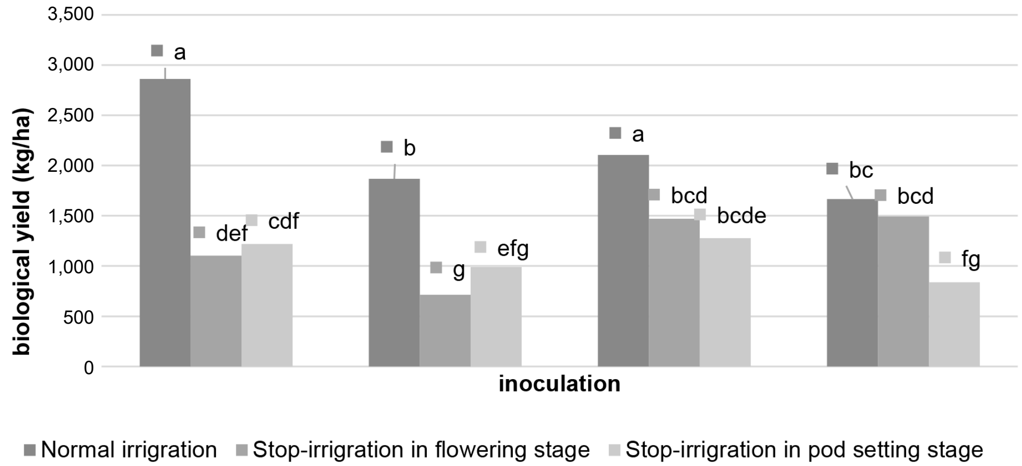

Figure 5 Interactive effects between drought stress and inoculations based on biological yield. Different letters indicating significant differences ($P < 0.01$)

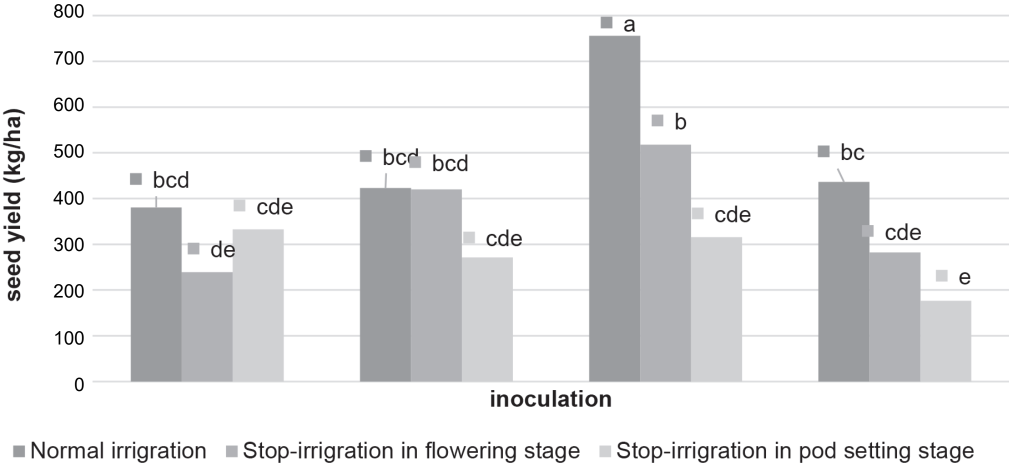

Figure 6 Interactive effects between drought stress and inoculations based on seed yield. Different letters indicating significant differences ($P < 0.01$)

Mycorrhizal Dependency (%) and Mycorrhizal Growth Response (%)

Glomus mosseae had the most mycorrhizal dependency. High percentage of mycorrhizal dependency displays the ability of fungous mycorrhizal to increase external hyphae network around the root. This ability of mycorrhizal as a plant symbiosis makes it possible for Mung bean to uptake water, minerals and nutrients from some area, where is not available for roots. Imposing drought in pod filling stage showed the highest mycorrhizal dependency. In drought condition, the mycorrhizal dependency in co−inoculated *Glomus mosseae* and *Pseudomonas fluorescens* 169 was more than other treatments. Plants in drought stress imposed plots in pod filling stage had less hair roots and displayed high mycorrhizal dependency in compare with plants growing in normal condition. Omidi *et al*. (2011) approved the highest mycorrhizal dependency for plants in drought stress condition.

According to Table 5, Mycorrhizal growth response in drought stress condition was more than in normal irrigation condition. Based on results *Pseudomonas fluorescence* 169 had the highest growth response in stopping irrigation in flowering stage. Under drought condition, plant symbiosis with *Pseudomonas fluorescence* 169 increased their availability for nutrients, water and minerals by producing hyphae and mycelium. It seems that IAA overproducing mutant of *Pseudomonas fluorescence* BSP53a stimulated root development in Mung bean (Glick, 2012).

Table 5 Mycorrhizal dependency (%) and Mycorrhizal growth response (%) of Mung bean (*Vigna radiata* L. Wilczek var. *Parto*) under drought stress condition

Treats	Mycorrhizal Dependency (%)	Mycorrhizal Growth Response (%)
No−inoculation	−0.01	−0.01
Glomus mosseae	0.004	0.007
*Pseudomonas fluorescens*169	0.001	0.002
G. mosseae+ *Pseudomonas fluorescens*169	0.0006	0.0006
Normal irrigation	0	−0.01
stoppinng−irrigation in flowering stage	0.01	−0.1
stopping−irrigation in pod setting stage	0.01	−0.01
Normal irrigation+ No−inoculation	0	0.01
Normal irrigation+ *Glomus mosseae*	0.007	0.017
Normal irrigation+ *Pseudomonas fluorescens*169	−0.0003	0.009
Normal irrigation+ *G. mosseae*+ *Pseudomonas fluorescens*169	−0.001	0.008
stoppinng−irrigation in flowering stage+ No−inoculation	0	0.006
stoppinng−irrigation in flowering stage+ *Glomus mosseae*	0.008	0.006
stoppinng−irrigation in flowering stage+ *Pseudomonas fluorescens*169	0.004	0.011
stoppinng−irrigation in flowering stage+ *G. mosseae*+ *Pseudomonas fluorescens*169	−0.001	0.009
stopping−irrigation in pod setting stage+ No−inoculation	0	0.004
stopping−irrigation in pod setting stage+ *Glomus mosseae*	0.004	0.007
stopping−irrigation in pod setting stage+ *Pseudomonas fluorescens*169	0.0003	0.006
stopping−irrigation in pod setting stage+ *G. mosseae*+ *Pseudomonas fluorescens*169	0.008	0.007

CONCLUSION

Interactive effects of soil microbial in sustainable agriculture to improve productivity of mung bean (*Vigna radiata* L. Wilczek) under drought stress was through suitable nutrient supply, biocontrol and improving soil structure. *Glomus mosseae* together *Pseudomonas fluorescens* strain 169 had synergistic effects on producing high number of seeds per plant, pod length and the number of pods per plant. *Glomus mosseae* symbiosis through increasing water, minerals, nutrients absorption increased pod diameter, the number of seeds per plant, dry weight of pods, biological yield producing high seeds yield. Drought stress decreased seed yield, biological yield, the number of seed per plant, the number of pods per plant, pod diameter and the number of seeds per pod, significantly. Over all, pod−setting stage of mung bean displayed more reduction in seed yield and yield components in comparison with flowering stage. In all, inducing drought resistance in pods setting stage achieved by soil microbial infection. In addition, relying on combination of *Glomus mosseae* and *Pseudomonas fluorescens* strain 169 in dry and semi dry area to increase tolerance and seed yield of Mung bean concluded. It seems that bacteria helping AM fungi through increasing competition between them in absorbing more water, nutrients and transporting nutrients toward reproductive parts caused increased seed yield. Inoculation of *Glomus mosseae* and *Pseudomonas fluorescence* 169 based on mycorrhizal dependency and mycorrhizal growth response respectively, in pod filling stages under drought condition increased external hyphae network. In all, insufficient water supply for irrigation and irrigation management has shifted from emphasizing production per unit area towards soil microbial and their interactions in environment.

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