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Research Article
Effects of *Mycorrhizae* and *Pseudomonas* Symbiosis on Growth Characteristics of Mung Bean (*Vigna radiata* (L.) wilczek) under Drought Condition

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Abstract
Background and Objective: Drought stress is one of the most common environmental stresses. It can affect productivity and growth characteristics of plants in different growth stages. The role of mycorrhizal symbiosis to protect plants in drought condition is considerable. The aim of this study was to improve growth parameters of mung bean by Mycorrhizae and *Pseudomonas* symbiosis as a natural technique under drought condition. **Materials and Methods:** This experiment was carried out in Research Farm of Islamic Azad University, Miyaneh branch, during summer 2016 based on split plot in Randomized Completely Block Design with 3 replications. Experimental plots were drought stress which includes; stopping irrigation in flowering stage, stopping irrigation in pod setting stage and normal irrigation. Inoculations as a second factor were included; non-inoculation (Control), inoculation with *Glomus mosseae*, *Pseudomonas fluorescens* 169 strain and *Glomus mosseae*+*Pseudomonas fluorescens* 169 strain. Analysis of data was performed using MSTATC and SPSS software. **Results:** There were significant variation ($p \leq 0.05$, $p \leq 0.01$) for drought stress treatments based on the majority of growth parameters and for inoculations except the number of leaves per plant, fresh weight of leaves and stem diameter. Drought stress reduced the majority of growth parameters of plant. As plant height Raised in drought imposed condition, the number of branches increased and caused increase in weight of plant. Traits included dry weight of stem+pod, dry weight of leaves and dry weight of plant explained 27.449% of total variations. **Conclusions:** It was concluded that inoculation of *Glomus mosseae* was more effective in increasing growth characteristics of mung bean. Pod formation stage was the most vulnerable growth stage of plant based on necessity for irrigation. Soil microbial could alleviate drought stress effects through enhancement plant height directly and dry weight of stem+pod, dry weight of leaves and dry weight of plant indirectly.

Key words: Mung bean (*Vigna radiata* (L.) wilczek), drought stress, *Glomus mossae*, *Pseudomonas*, growth parameters

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Mung bean is an annual plant from legume family and native of India. The center of Asia as an origin of this plant also reported[1]. Mung bean is a warmlike and short day plant and its necessity for hot temperature is high[2]. The production amount of Mung bean estimated 1.2 million tons annually in the world. This amount harvested from 3 million ha farm lands[3]. Investigations in Iran have displayed that lands devoted for planting mung bean is about 25,000-30,000 ha[4]. It has the fifth location among all grain legumes. In Iran, mung bean (*Vigna radiate* (L.) wilczek) is planted in center, Southeast and Southwest of country. Mung bean's productivity in Iran is estimated 15,000 ton annually[4].

Recently climate changing and Global warming are accompanied with changing in planting patterns in different places. This climate changing is the main reason to increase temperature in some regions which leads to have drought or water deficiency phenomena. Water deficit is one of the major abiotic stresses, which adversely affects crop growth and yield[5].The main effect of drought stress in the first hand is the interest of farmers to have tropical plants in their own farms as new plants with high adaptation. It makes researchers to be more eager and think to discover some ways to increase the productivity of plants in new places. The authors speculate that in sustainable agriculture more emphasis should be on using some natural techniques and ways to improve plant's productivity, without any detrimental effect on environment and be in favor of plant, soil and water entirely. Symbiosis interaction between fungi, bacteria, soil and root of plants is one technique, which is feasible to use in farm. The efficiency of symbiosis systems in improving plant's tolerance and their productivity depends on varieties of plant and type of fungi or bacteria. Besides, drought stress can occur in different growth stages of plant. The most important growth stages of Mung bean (*Vigna radiata* (L.) wilczek) is flowering and pod formation. In addition, MA symbiosis has a variety of effects on defensive response of host plants, depending on the species of host plant and the AM fungus involved[6]. Mycorrhizal symbiosis has key role in cycling nutrition in ecosystem and can increase the resistance of plants against environmental stresses[7]. There was a report confirmed that inoculation with *Glomus mosseae* and *Piriformospora* had positive effect and was useful in stress and none stress conditions[8]. Habibzadeh *et al*.[9] displayed that mycorrhizae species affected grain yield of mung bean through their effects on pod length, seeds/pod, pods/plant and seeds/plant under well-watered and drought stress conditions. Mycorrhizal symbiosis mostly causes altering in the speed of water movement inside, outside and all over of host plant and affects on physiological activities and absorbing water of leaves[10]. It seems that dry and fresh weights of different vegetative parts of mung bean as physiological indicators are convenience indices to predict changes happening during growth stages. Productivity of Plant under drought stress is strongly related to the processes of dry matter partitioning and temporal biomass distribution[11]. Greater plant fresh and dry weights under water limited conditions are desirable characters. A common adverse effect of water stress on crop plants is the reduction in fresh and dry biomass production[5]. In addition, drought stress causes decrease in rate of plant's growth. The number of leaves and branches also decrease and plant flowering stage begins earlier[12]. Ortiz *et al*.[13] reported that mycorrhizal inoculation significantly (at 5% level) enhanced plant growth, nutrient uptake particularly when associate with specific bacteria minimizing drought stress-imposed effects. They suggested that microbial activities irrespective of microbial origin seems to be coordinately functioning in the plant as an adaptive response to modulate water stress tolerance and minimize the stress damage by increasing leaf surface, dry weight of different growth parts. One study released that *Pseudomonas fluorescens* enhanced the growth parameters in *Catharanthus roseus* under drought stress and partially ameliorated the drought induced growth inhibition through increasing the fresh and dry weights significantly[14]. Arbuscular Mycorrhizal (AM) fungi and bacteria can interact synergistically to stimulate plant growth. These interactions may be of crucial importance within sustainable, low-input agricultural cropping systems[15]. So that, optimized combinations of micro-organisms with high ability to alleviate drought stress effected on plant growth organs can help to have high yield in organic cropping systems as well as biologically increased resistance of plants in arid and semi-arid area. Experiments in the field of irrigation time emphasize on avoidance drought stress before and during flowering stage to have optimum yield[16-18]. The main objective of this investigation was to recommend an appropriate symbiont with Parto variety of mung bean having more positive and significant ($p \leq 0.05$, $p \leq 0.01$) effects on vegetative parts of plant in drought imposed condition in Miyaneh region, Iran.

MATERIALS AND METHODS

Plant material: Parto cultivar of Mung bean (*Vigna radiata* (L.) wilczek) was used in this study, which was provided from Seed and Plant improvement Institute, Karaj, Iran. Suspension solution of *Pseudomonas fluorescens* 169 strain with 10^8-10^9 live and active bacteria mL^{-1} (CFU mL^{-1}) was provided from Water and Soil Research Institute, Karaj, Iran. *Glomus* *mosseae* was provided from Zist Fanavaran Company. It had approximately 30 live fungi in per gram soil and was produced by culturing in host plant which used in form of soil mixed spores and hyphae.

Experimental design: The experiment was conducted in research farm of Islamic Azad University, Miyaneh branch, Iran (37°55' N; 47°11' W; elevation 1100 m) during the year summer of 2016 in RCBD based split plot design with 3 replications. Experimental plots were drought stress including; stopping irrigation in flowering stage, stopping irrigation in pod formation stage and normal irrigation. Inoculation as a second factor with 4 levels including; non-inoculation as control, *Glomus mosseae*, *Pseudomonas fluorescens* 169 strain and *Glomus mosseae*+*Pseudomonas fluorescens* 169 strain. Parto cultivar of Mung bean (*Vigna radiata* (L.) wilczek) sown in 6 rows, 3×1.5 m^2, with 50 cm inter-row spacing. All agricultural practices done in farm were based on IAUM guideline (Fig. 1). The results of soil physical and chemical analysis of research area indicated soil structure was clay and amount of organic carbon, nitrogen, phosphorous and potassium in experimental farm were 1.5, 0.1%, 5.70 and 301 ppm, respectively. During the experiment any substance such as fertilizer was not applied. Monthly total rainfall in May, June, July and August, 2016 were 15.8, 0.4, 0 and 20.3 mm and average temperature were 23, 27.95, 29 and 25.9°C, respectively.

Data measurement:

- **Plant height (cm):** Average of 5 selected plants measured
- **Number of leaves:** Average number of leaves in 5 selected plants counted
- **Dry weight of leaves (g):** Average of total dry weight of leaves in 5 selected plants measured by means of digital scale
- **Dry weight of stem and pod (g):** Average dry weight of stem and pod of 5 selected plants measured by digital scale
- **Dry weight of plant (g):** Which included dry weight of stem and leaves+ pods of 5 selected plants from each plot
- **Fresh weight of stem and pods (g):** After picking leaves up, average fresh weight of stem in 5 plants obtained
- **Fresh weight of leaves (g):** Average fresh weight of leaves measured from 5 selected plants
- **Fresh weight of plant (g):** Total fresh weight of 5 selected plants calculated and measured
- **Number of branches:** Number of branches having leaves in 5 selected plants randomly counted
- **Stem diameter:** 5 plants selected for each experimental plot and stem diameter of plants from the first internode measured by means of caliper

Fig. 1: Mung bean (*Vigna radiata* (L.) wilczek) experimental research farm (IAUM)

Statistical analysis: Analysis of data was performed using MSTATC software (Manufactured by Plant and Soil Sciences, Michigan State University, East Lansing,) and Duncan's mean comparison at level of 5%, correlation coefficients and factor analysis were calculated with SPSS software[19] (Produced by SPSS Inc., it was acquired by IBM in 2009, Version 16).

RESULTS AND DISCUSSION

Plant height: Plant height is trait intensively related to environmental factors. As Table 1 shown, there were significant differences between height of mung bean imposing drought stress in different growth stages ($p \leq 0.05$). In fact, drought stress both in flowering and pod formation stages significantly reduced the plant height ($p \leq 0.05$). Based on mean comparison results, the plant height observed in stopping-irrigation in flowering and pod setting stages were 19.227 and 17.187 cm, respectively. The highest of this trait observed in normal irrigation which was 24.375 cm (Table 2). Reduction in plant height is associated with a decline in the cell enlargement. In addition, Reduction in plant height in drought condition is a mechanism that plants through uptaking less water will decrease some of their growth regulators which are responsible for cell division and enlargement of them, such as cytokenin. Results displayed that based on plant height, pod formation stage was more sensitive to drought stress in comparison with flowering stage. Based on statistical analysis, differences among types of inoculation and inoculation×drought stress were significant at 1 and 5% of probability level respectively (Table 1). Highest amount of plant height was observed by *Glomus mosseae* inoculation with average of 24.106 cm (Table 3). The role of *Glomus mosseae* to improve cell division and enlargement of them and consequently plant height was significant (Table 3).

Table 1: Mean squares of growth characteristics of mung bean (*Vigna radiata* (L.) wilczek) under different inoculations and drought stress condition

		Mean Squares (MS) of mung bean (*Vigna radiata* (L.) wilczek)				
Sources of variance	Degree of freedom	Plant height (cm)	No. of leaves	Dry weight of leaves (g)	Dry weight of stem+pod (g)	Dry weight of plant (g)
Replication	2	9.307	177.620*	0.604	0.211	1.527
Stress(a)	2	164.775*	307.863*	5.747*	31.417*	62.897*
Error(a)	4	23.721	25.993	0.539	3.525	5.804
Inoculation(b)	3	61.125**	25.651	3.278*	5.318*	8.538*
Inoculation×Stress	6	35.261*	33.321	0.450	2.104	3.646
Error(b)	18	6.779	17.729	0.820	1.793	2.908
Total	35					
Coefficient of variation %	-	12.85	17.78	25.48	16.61	14.68

		Mean Squares (MS) of mung bean (*Vigna radiata* (L.) wilczek)				
Sources of variance	Degree of freedom	Fresh weight of stems (g)	Fresh weight of leaves (g)	Fresh weight of plant (g)	Stem diameter (mm)	No. of branches
Replication	2	92.236*	22.636	167.702	1.456	5.272*
Stress(a)	2	35.951	166.118*	197.498	1.354	6.831*
Error(a)	4	10.998	24.223	55.341	0.913	0.597
Inoculation(b)	3	85.234*	9.333	138.831*	0.225	2.736**
Inoculation×Stress	6	26.955	14.210	64.599	0.773	1.138
Error(b)	18	17.406	10.090	37.035	0.556	0.531
Total	35					
Coefficient of Variation %	-	23.73	24.57	19.96	14.71	10.58

*,**Significant in probability level of 5 and 1%, respectively

Table 2: Mean comparison of growth characteristics of mung bean (*Vigna radiata* (L.) wilczek) under drought stress condition

Drought stress	Plant height (cm)	No. of leaves	Dry weight of leaves (g)	Dry weight of stem+pod (g)	Dry weight of plant (g)
Normal irrigation	24.375^a	28.718^a	4.289^a	9.914^a	14.203^a
Stopping-irrigation in flowering stage	19.227^b	23.733^b	3.456^b	7.330^b	10.786^a
Stopping-irrigation in pod setting stage	17.184^b	18.588^c	2.916^b	6.935^b	9.856^b

Drought stress	Fresh weight of stems (g)	Fresh weight of leaves (g)	Fresh weight of plant (g)	Stem diameter (mm)	No. of branches
Normal irrigation	19.557^a	13.323^b	32.878^a	5.457^a	7.496^a
Stopping-irrigation in flowering stage	16.585^a	9.023^c	25.805^b	4.870^a	7.129^a
Stopping-irrigation in pod setting stage	16.329^a	16.433^a	32.785^a	4.880^a	6.045^b

Means followed by same letters are not significantly different at Duncan's mean comparison test at (5%)

Table 3: Mean comparison of growth characteristics of mung bean (*Vigna radiata* (L.) wilczek) with different inoculations

Inoculation	Plant height (cm)	No. of leaves	Dry weight of leaves (g)	Dry weight of stem+pod (g)	Dry weight of plant (g)
No-inoculation	18.456[b]	21.690[a]	3.067[b]	8.344[a]	11.411[ab]
Glomus mosseae	24.106[a]	25.033[a]	4.426[a]	7.950[a]	12.376[a]
Pseudomonas fluorescens 169	18.553[b]	25.129[a]	3.259[b]	7.060[b]	10.319[b]
G. mosseae+*Pseudomonas fluorescens* 169	19.603[b]	23.867[a]	3.463[b]	8.884[a]	12.354[a]

Inoculation	Fresh weight of stems (g)	Fresh weight of leaves (g)	Fresh weight of plant (g)	Stem diameter (mm)	No. of branches
No-inoculation	13.460[b]	12.006[a]	25.458[b]	4.869[a]	6.694[b]
Glomus mosseae	20.544[a]	13.597[a]	34.071[a]	5.071[a]	6.621[b]
Pseudomonas fluorescens 169	17.167[ab]	12.108[a]	29.332[ab]	5.256[a]	7.711[a]
G. mosseae+*Pseudomonas fluorescens* 169	19.156[a]	13.995[a]	33.096[a]	5.080[a]	6.533[b]

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

Influence of mycorrhizal in uptaking nutritional elements such as phosphorous, nitrogen and potassium are the most important mechanism in relation to vegetative growth of plants[20,21]. Interaction between drought stress and type of inoculation displayed the highest and positive effectiveness of *Glomus mosseae* in normal irrigation condition on plant height (Fig. 2). Arbuscular Mycorrhizal has an ability to extend external spores and alter morphology of root, root uptaking level and raising the transportation of food toward roots of the plants[22]. In Conclusion, the effectiveness of *Glomus mosseae* in increasing plant height was more than *Pseudomonas fluorescens* 169 strain and combination of both.

Number of leaves: Mashayekhi and Mousavizadeh[23] introduced the number of leaves per plant as a criterion to distinguish different growth stages of plants. According to growth characteristics of mung bean (*Vigna radiata* (L.) wilczek) under inoculation and drought stress condition, there was significant variation among drought stress imposed in different growth stages ($p<0.05$) based on the number of leaves in a plant (Table 1). Average the number of leaves in normal irrigation was highest and in stopping irrigation in pod formation stage was the lowest with average number of 28.718 and 18.588 leaves, respectively (Table 2). Therefore, drought stress in pod formation stage had more harm effect on the number of leaves in plant. Reduction in growth characteristics of plants in drought stress condition reported in savory (*Satureja hortensis* L.)[24] and wheat[25]. While, there were not any significant differences among inoculations based on the number of leaves statistically but inoculation with *Glomus mosseae*, *Pseudomonas fluorescens* 169 strain and both fungous and bacteria with 25.033, 25.129 and 22.867 had the highest leaf number in comparison with no-inoculation (Table 3). So, the number of leaves in mung bean less affected by soil microbial. It seems that exchanging nutrition between plant's roots and microorganisms caused to never have any variation in the number of leaves. As a results, relying on soil microbial effects to alleviate drought stress influences by the number of leaves is not approved.

Dry weight of leaves: Mean squares results illustrated that there were significant differences among drought stress and inoculation in probability level of 5% (Table 1). The highest average dry weight of leaves occurred in normal irrigation with 4.289 g. Imposing drought stress in both flowering and pod setting stages decreased dry weight of leaves. The lowest dry weight of leaves produced with 2.916 and 3.45 g in drought stress imposed plots in pod setting and flowering stages (Table 2). In all, water deficit in every growth stages of plant reduced uptaking, transportation and consumption of nutrients. The consequences were reducing carbon storage and dry matter of plant[26]. Inoculation with *Glomus mosseae* caused the highest increase in dry weight of leaves. Average the dry weight of leaves produced by *Glomus mosseae* inoculation was 4.426 g (Table 3). Therefore, inoculation with arbuscular mycorrhiza was effective to increase growth indexes of plant such as dry weight of leaves. Results confirmed that soil microbial can help plant to increase weight and surface of leaves rather than stimulation the number of leaves. Mycorrhiza symbiosis often leads to altering speed of water movement in and outside of host plant and had influence on inundation of tissue and physiology of leaves[27].

Dry weight of stem+pod: The results of Mean square showed that differences among drought stress and inoculation were significant ($p\leq 0.05$). The same results were also reported[9]. Mean comparison displayed variation in dry weight of stem+pod from 9.914 g in normal irrigation to 6.935 g in stopping irrigation in pod formation stage (Table 2). Differences in uptaking water, minerals and producing dry matter in different irrigation intervals is the important factor in Crop Growth Rate (CGR) changes of plant[9]. High average the

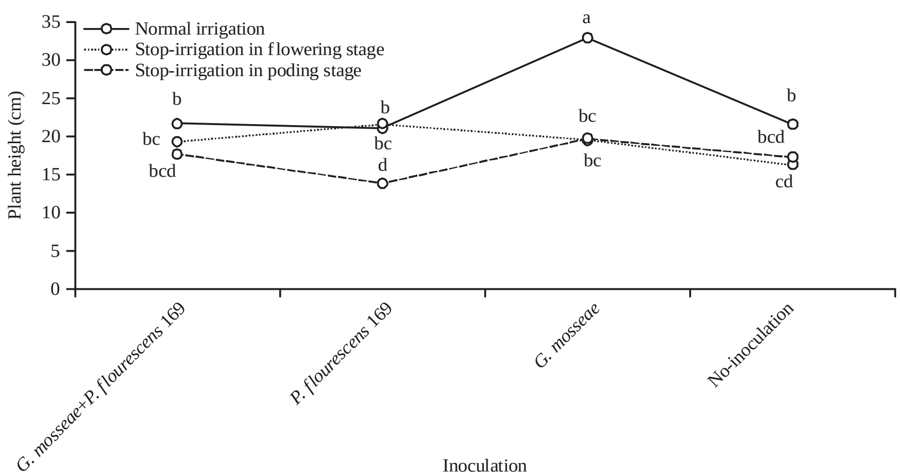

Fig. 2: Interaction effects of drought stress and type of inoculation on height of mung bean (*Vigna radiata* (L.) wilczek)
Means followed by same letters are not significantly different at Duncan's mean comparison at (5%)

dry weight of stem+pod produced in inoculation of mung bean (*Vigna radiata* (L.) wilczek) with combination of *Glomus mosseae*+*Pseudomonas fluorescens* 169 strain was 8.884 g which was insignificant with *Glomus mossae* inoculation as shown in Table 3. Some bacteria living soil are the third part of the root fungi collection which can improve symbiosis relationship and are recognized as auxiliary bacteria[28]. In addition, some bacteria has an auxiliary effects on both plant and mycorrhizal symbiosis. So, positive synergistic effect of *Glomus mosseae* and *Pseudomonas fluorescence* 169 strain in dry weight of stem+pod was significant (Table 3) .As a result, optimized combination of *Glomus mosseae* and *Pseudomonas fluorescence* 169 can be applied as an effective inoculants within sustainable crop production systems. It seems that *Pseudomonas fluorescence* 169 by increasing root surface and helping to propagate *Glomus mosseae* mycelia allows plant to absorb more nutrition and mineral producing high stem+pod dry matter. So, Inducing lateral roots formation is one of the visible attitudes of Auxiliary bacteria. Bacteria mainly enhance mycorrhizae formation as a result of promotion of fungal growth, leading to changes in fungal gene expression and have strongest effect on the growth of mycelia[29].

Dry weight of plant: Analysis of data presented in Table 1, turned out that drought stress had an adverse effect on total dry weight of mung bean. Differences among inoculation factors based on total dry weight of plant were significant in level of 5% statistically (Table 1). Mean comparison of traits displayed that *Glomus mosseae* was more effective in increasing dry weight of plant. In fact, *Glomus mosseae* through providing more nutrients, minerals and water for root and shipping them toward upper parts of plant produced the highest dry weight with average 12.376 g which was insignificant with inoculation of *Glomus mosseae*+ *Pseudomonas fluorescence* 169 producing dry weight of plant (Table 3). This finding of research may be appropriate for physiologist in their further investigation on soil microbial and plant growth indices in Parto variety of mung bean. Others reported that inoculation of plants with *Glomus mossea*e and *Glomus intraradices* in flowering to ripping stage displayed highest amount of Total Dry Weight (TDW), Leaf Dry Weight (LDW), Leaf Area Index (LAI), Relative Growth Rate (RGR), CGR and Net Assimilation Rate (NAR) in comparison with no inoculation[9]. Results showed that stopping irrigation in pod formation stage had the most negative effect on dry weight of plant with producing 9.856 g (Table 2). It has been proved that flowering and pod filling stages are the most susceptible stages to soil moisture stress and supplement irrigation, particularly in pod filling stage, improves final performance which results an increment in yield components[30].

Fresh weight of stems: Results represented significant difference among all inoculations based on the fresh weight of stems in probability level of 5% (Table 1). Mean comparison illustrated that inoculation with *Glomus mosseae* had a high influence on the fresh weight of stems with producing 20.544 g. There were no any significant differences among inoculation of *Glomus mosseae* and *Glomus mosseae*+*Pseudomonas fluorescens* 169 strain statistically (Table 3). It indicated that mycorrhizal symbiosis had an effective role in increasing the fresh weight of stems in comparison with no-inoculation. In addition, greater rooting depth helps to acquire stored water from various depths to improve stability of stem. In conclusion, fungi and bacteria symbiosis by increasing stem height could produce high fresh weight. Therefore, root-Fungi symbiosis is a pivotal part in plant ecology. It means mycorrhizae are able to create a vast connection between roots of the plant and soil around, which allows them to uptake nutrients such as nitrogen and phosphorus efficiently and increase the surface area of the roots[31]. It makes clear that with this increased surface area, the plants will have many benefits such as high stability.

Fresh weight of leaves: Drought stress affects the fresh weight of leaves. But, drought in pod setting stage produced high average fresh weight of leaves even more than in normal irrigation plots (16.433 g) (Table 1, 2). Somehow, it related to intrinsic capacity of mung bean growing in high temperature. Varma and Subba-Rao[32] reported that seed yield, dry weight of nodule and nitrogen content of mung bean (*Vigna radiata* (L.) wilczek) declined in high level of moisture in pot experiments.

Fresh weight of plant: Results from mean square analysis displayed a significant difference among inoculations for the fresh weight of plant in probability level of 5%, while there was not any differences among drought stress and interaction with inoculation (Table 1). Mean comparison showed that imposed drought stress declined the fresh weight of plant. In addition, the highest fresh weight of mung bean obtained in normal irrigation which was insignificant with treatment of stopping irrigation in pod setting stage and the lowest was in stopping irrigation in flowering stage with 32.87 and 25.80 g, respectively. There are evidence on reduction in morphological parameters of mung bean (*Vigna radiata* (L.) wilczek) in drought condition[3,33]. It seems that reduction in the number of leaves is the main factor to decline fresh weight of plant in water stress condition. Based on mean comparison results in Table 3, mycorrhizal symbiosis had high and positive influence in increasing the fresh weight of plant. Producing 34.07 g fresh weight by inoculation of *Glomus mosseae* is an indicator of high potential for this fungi in symbiosis with root of mung bean and increasing growth characteristics of plant which was insignificant with inoculation of *Glomus mosseae*+*Pseudomonas fluorescens* 169.

Number of branches: Because of the important role for the number of branches in determination of leaf number and consequently amount of photosynthesis, studying of this trait in drought stress condition is very vital. Variation between drought and type of inoculation was significantly differ at $p \leq 0.05$ and $p \leq 0.01$ respectively, based on the number of branches per plant (Table 1). In addition, declining the number of branches in water stress conditions in comparison with normal irrigation was significant (Table 2). The number of branches in normal irrigation plots were insignificant with stopping irrigation in flowering stage having 7.496 branches. Stopping irrigation in pod formation stage with 6.045 branches was the lowest value (Table 2). In Table 3, inoculation of *Pseudomonas fluorescens* 169 strain with 7.711 branches was more effective in raising the number of branches in plant. It seems that effectiveness of *Pseudomonas fluorescence* 169 strain on genes responsible in increasing the number of branches was more than other traits. The positive influence of *Pseudomonas fluorescens* in increasing plant branches was reported by other researchers [34].

Multivariate analysis: Multivariate approaches were widely applied based on interaction data to simplify complex correlations observed among the measured characteristics.

Correlation coefficient: Pearson's correlation coefficient is a statistical method of quantifying the association, or "coherence", between two variables. Therefore, It is very popular tool to analyze data arise in many scientific disciplines, for instance in biology[35]. Plant height had the highest correlation with the number of leaves, dry weight of plant, dry weight of leaves, fresh weight of stems and the number of branches with 0.618, 0.489, 0.484, 0.471and 0.406 coefficients respectively as shown in Table 4. It shows that as plant height raised, the number of branches increased and caused increase in the weight of plant. There is a report confirmed that using *Glomus* genius fungi infection increased plant height, fresh and dry yield of plant[36]. Having no significant correlation between the number of leaves per plant and the fresh weight of leaves displayed that increasing in fresh weight of leaves perhaps was due to increasing in LAI of each single leaf without effect of the number of leaves per plant. Again, as we can see in Table 4, there was highest correlation coefficients between dry weight of stem+pod and dry weight of plant which is an indicator of direct and positive effect of them in increasing total biomass of plant. There was rational correlation among the dry weight of plant with the fresh weight of plant, fresh weight of stems, plant height, the number of leaves and dry weight of leaves in probability level of 1% and with the number of branches in probability level of 5% (Table 4). All indicate that in drought stress condition symbiosis interaction of plant with mycorrhizal helped to uptake more minerals and water, which can lead to have a high fresh weight through increasing stem height and fresh weight of stems. The high and positive correlation coefficients

Table 4: Correlation coefficient among all growth characteristics of mung bean (*Vigna radiata* (L.) wilczek)

Traits	Plant height (cm)	No. of leaves	Dry weight of leaves (g)	Dry weight of stem+pod (g)	Dry weight of plant (g)	Fresh weight of stems (g)	Fresh weight of leaves (g)	Fresh weight of plant (g)	Stem diameter (mm)
Plant height	1								
No. of leaves	0.618**	1							
Dry weight of leaves	0.484**	0.457**	1						
Dry weight of stem+pod	0.393*	0.343*	0.467**	1					
Dry weight of plant	0.489**	0.441**	0.755**	0.932**	1				
Fresh weight of stems	0.471**	0.585**	0.514**	0.399*	0.506**	1			
Fresh weight of leaves	0.083	0.045	0.066	0.183	0.163	0.407*	1		
Fresh weight of plant	0.337*	0.376*	0.378*	0.367*	0.126**	0.853**	0.788**	1	
Stem diameter	0.219	0.599**	0.321	0.159	0.249	0.302	-0.246	0.055	1
No. of branches	0.406*	0.637**	0.328	0.342*	0.388*	0.546**	0.286	0.492**	0.356*

*'**Significant in probability level of 5 and 1%, respectively

Table 5: Factor analysis after orthogonal rotation for growth characteristics of mung bean (*Vigna radiata* (L.) wilczek)

	Factors		
Traits	1	2	3
Plant height (cm)	0.465	0.507	0.164
The number of leaves	0.264	0.864	0.164
Dry weight of leaves (g)	0.722	0.353	0.101
Dry weight of stem+pod (g)	0.897	0.062	0.157
Dry weight of plant (g)	0.960	0.191	0.158
Fresh weight of stems (g)	0.332	0.507	0.656
Fresh weight of leaves (g)	0.037	-0.164	0.917
Fresh weight of plant (g)	0.252	0.216	0.916
Stem diameter (mm)	0.090	0.813	-0.219
No. of branches	0.172	0.647	0.432
Total	2.745	2.579	2.460
% of variance	27.449	25.786	24.596
% cumulative	27.449	53.235	77.831

between dry weight of stem+pod and dry weight of plant showed that the effectiveness of fungi and bacteria in water deficit condition was mostly through stimulation of stem and pod growth.

Principal component: Factor analysis is a multivariate statistical method to evaluate relationships among traits and find independent factors that explain phenotypic viability in genotypes accurately[30]. In this study, factor analysis was used according to principal component analysis after orthogonal rotation based on interaction data. Factor analysis distributed all ten variables in three factors. For better explanation only factors with coefficients more than 0.5 without paying attention to their signs selected as significant coefficients in each independent factor. The 1st factor explained 27.449% of total variations, where the dry weight of leaves, dry weight of stem+pod and dry weight of plant considered as the most important traits (Table 5). There was positive and significant relationship among above mentioned traits (Table 4). The 2nd factor contained 25.786% of total variations. In this factor plant height, the number of leaves, stem diameter and the number of branches had the highest coefficients. Eventually, the 3rd factor included 24.596% of total variations and coefficients for fresh weight of stems, fresh weight of leaves and fresh weight of plant were 0.656, 0.917 and 0.916, respectively which had the highest value (Table 5). In conclusion, in water deficit condition the effectiveness of soil microbial was through improving significant considered traits on factor 1 included dry weight of stem+pod, dry weight of leaves, dry weight of plant. Physiologists can get the benefits of this result for their future investigations on interaction between arbuscular mycorrhizal fungi and bacteria and their potential for stimulating plant growth in water stress condition.

CONCLUSION

This study indicated major differences between fungi, bacteria and interaction of them in their ability to enhance growth characteristics of mung bean. Soil microbial could alleviate drought stress effects through enhancement plant height directly. Pod formation stage of mung bean distinguished as susceptible growth stage of plant in water deficit condition. In addition, stopping irrigation in pod formation stage had high negative influence on measured growth parameters studied except fresh weight of leaves and fresh weight of plant. The majority of measured growth characteristics affected positively by soil microbial. Synergistic effects of *Glomus mosseae* and *Pseudomonas fluorescens* 169 inoculation increased stem+pod weight and dry weight of plant which can be fruitful result for physiologists and soil scientists to use *Glomus mosseae* infection as an efficient symbiont with Parto variety of mung bean in their future research. Multivariate analysis to recognize the role of *Glomus mosseae*, *Pseudomonas fluorescens* 169 and combination of *Glomus mosseae*+*Pseudomonas fluorescens* 169 in alleviation harm effects of drought stress through improving growth parameters of plant approved. Another major finding of this investigation was relying more on dry weight of stem+pod, dry weight of leaves and dry weight of plant as great parameters for further physiological investigations.

SIGNIFICANCE STATEMENT

This study discovers the role of fungi and bacteria and their interaction to ameliorate harm effects of drought stress on growth parameters in Parto variety of mung bean, that can be beneficial in arid and semi-arid area. This study will help the researchers to uncover the critical areas of Mycorrhizal and bacteria interaction especially in sustainable and low-input agriculture systems that many researchers were not able to discover. Thus, the new theory on soil microbial and possibly of interaction between them is relying more on *Glomus mossae* infection to improve growth parameters of mung bean under drought stress condition

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