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Original article

Application of bio-fertilizers for enhancing growth and yield of common bean plants grown under water stress conditions

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A R T I C L E I N F O

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A B S T R A C T

This study was planned to enhance the growth and productivity of common bean plants (*Phaseolus vulgaris* L.) grown under different water stress level by using different microorganisms as bio-fertilizer agents. Water stress is a international problem that effects on morphological, functional and chemical processes of plants occasioning in altering growth, yield and water relations of economic plants like common bean plants. The interaction effect between water stress (WW as recommended irrigation after 6 days, WS1 after 12 days and WS2 after 18 days) and inoculation with different microorganisms [AMF (*Glomus mosseae*) and endophytic bacteria, (*Bacillus amyloliquefaciens*)] used alone or in mixed was examined on the development and productivity of common bean plants. Mutual application of AMF and endophytic bacteria significantly increased the average values of most of growth, water relations (photosynthetic rate, transpiration rate and stomatal conductance) and yield parameters of common bean plants grown at WS1 and WS2 comparing with non-colonized plants. In this connection, colonization with AMF and endophytic bacteria with WS1 are the greater pods number, pod length, pods weight, 100 seeds weight, Yield by ton /Fed and water-use efficiency (WUE) by ton/ m^3 than other treatments. Common bean yielded seeds had significantly increased nutrients content (nitrogen, potassium, phosphorus, magnesium and calcium), vitamin B_1, Folic acid, crude protein and crude fibers at AMF + endophytic bacteria under second water stress (WS1) when compared to other treatments.

1. Introduction

Phaseolus vulgaris plants. is a herbaceous yearly plant and foremost grain legume disbursed universal for its eatable seeds and shells (Karami, 2015). Furthermore, it is unique of five cultured type from the genus *Phaseolus* which is third in position after peanut and soybean, but first in direct human eating (Broughton et al., 2003). In Saudi Arabia, common bean is unique of the best vital field yields. It is cultivated throughout the country and widely consumed as vegetables and also as dry seeds.

Water stress is one of the chief boundaries on plant efficiency wide-reaching and is valued to upsurge with climatic differences. Chief encounter opposite Saudi Arabia currently is the sturdy essential for improved spread and society of the obtainable incomplete funds of water, land and vitality to encounter the requirements of a population progress (Asrar and Elhindi, 2011). They are using new tools to simplify and rise the invention of this plant, such as irrigation and mechanical gathering due to consume beans daily (Wu and Xaia, 2006). Crop and vegetables plant are uncovered to a change of environmental rigidities, such as water stress, saline filling and chilly that inspiration their progress, growth and yield (Aseel et al., 2019). Unique of the major abiotic stresses that affect plant productivity is drought resulting from water and salt stresses (Auge, 2001). Drought disturbs functional and chemical practices of plants (De Almeida et al., 2017), subsequent in varying growth, harvest and water status (Abdel-Fattah et al., 2002) and metabolic pathways (Maggio et al., 2000). Lessening in plant development below water tightness is due to osmotic stress occasioned from reducing soil aquatic imminent and acceptance of nutrients (Stanhill, 1986; Asrar et al., 2012).

Arbuscular mycorrhizal fungi (AMF) are abundant soil microbes and classified under phylum Glomeromycota that progress a mutualistic synergy with the great mainstream of terrestrial plants (Smith and Read, 2008). Mycorrhizae are mutualistic symbiotic

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associations based on bidirectional nutrients among soil fungi and the roots of higher plants, where AMF transfer mineral nutrients and water to the plant and obtain carbohydrates from the plant (Abdel-Fattah et al., 2016).

Arbuscular mycorrhizal (AM) mycological association is commonly understood that it guards multitude plants from harmful properties of water stress (Auge, 2001; Abdel-Fattah et al., 2002; Ruiz-Lozano, 2003; Asrar and Elhindi, 2011). Potential apparatuses for humanizing water stress fighting of the AM plants may probably be owed toward an amplified in root hydraulic conductivity (Robert et al., 2008), stomatal guideline or transpiration rate (Allen and Boosalis, 1983), enriched aquatic commitment at low soil moisture levels as a result of extra radical hyphae (Fagbola et al., 2001), osmotic alteration which encourages turgor conservation level at low material water prospective (Auge, et al., 1986), improved photosynthetic movement, proline and carbohydrate gathering, and improved nutritive status in AMF plants (Scheilenbaum, et al., 1999). These apparatuses might be imperative in revision of the AMF plants to deficiency circumstances. The association of plant roots with arbuscular mycorrhizal fungi is notorious to be one of the greatest earliest and prevalent plant approaches to increase nutrient gaining which manages with the conservational tension.

Endophytes counting molds and bacteria that employ the complete of their Life cycle inhabiting in existing material of dissimilar plants naturally deprived of instigating any obvious signs of disease (Sandhu et al., 2014). Therefore, application of endophytic bacteria resulting in creation of phytohormones, bio control of pathogens in the root region (concluded manufacture of antifungal or antibacterial agents, siderophore invention, antagonism of nutrient and initiation of organized attained congregation fighting, or immunity) or by improving obtainability (Deshmukh et al., 2014; Bagchi, 2018; Rashad et al., 2020).

Using microbial knowledge as a natural method for relieving the opposing effects of water stress motivation be the greatest different option ecologically and economically. It significantly recovers the excellence and fruitfulness of soil as well as the development and excellence of crops by enlightening soil construction, prominent to better aeration and water holding capacity, increasing bacterial stability, enlightening seed spread, plant growth, root development, flowering, ripening and maturing, enhancing nutrient availability and plant nutrient uptake, dropping disease pressure by evolving a disease oppressive soil, lowering necessities for insecticides, and attractive plant photosynthetic ability and protein movement (Wu and Xaia, 2006; Asrar and Elhindi, 2011). In this connection, this study evaluated to study the functional role of arbuscular mycorrhizal fungi (AMF) and endophytic bacteria as bio-fertilizer agents for alleviating of the water stress and also improving the growth and yield production of common bean plants under dissimilar water stress altitudes.

2. Material and methods

2.1. Plant and growth conditions

This study was conducted at the investigation Station of the Faculty of Science, King Saud University, during the last week of March to the last week of June 2019. Healthy uniformed common bean seeds were surface disinfected in a 7% NaClO solution for 4 min. and washed directly with disinfected water and dried on sterile filter paper which was divided into two sets. First set: For AMF managements (AMF), each plastic pot was inoculated with 4 g of rhizosphere soil (around 250 spores.g^{-1} soi1) and 0.5 g of cutted arbuscular mycorrhizal (AM) fresh sudangrass roots infected with *Glomus mosseae* (M = 88.6%). Beneath the soil superficial of common bean plants, the inoculum was located 4–5 cm to produce arbuscular mycorrhizal (AM) plants. The unmycorrhizal treatment customary an equivalent quantity of autoclaved soil and infected roots inoculum to afford the equal microflora without mycorrhizal fungi. Second set: the endophytic bacteria were added in a presoaking way for the common bean seeds for one hour at planting time, and the second time in a foliar way after 30 days from sowing. Immediately after the period of soaking, the seeds were washed with sterile water and 5 grains were placed in each plastic pot (30 cm in size) containing 8 kg substrate (sand: clay, 2: 1 v/v). After two weeks of planting, the plants were thinned in each pot to one plant, leaving the homogenous plants separated. The plants in the first and second sets were divided into three groups: 1st was irrigated with normal water every 6 days (WW), 2nd irrigated every 12 days (WS1) and the 3rd set was irrigated every 18 days (WS2). All pots were arranged on a glasshouse under normal environmental conditions in a randomized block design. After three weeks of planting, all plants were fertilized with 35 g N of ammonium nitrate (N m^{-2}) and 35 g P of super phosphate (P m^{-2}). Gathering (ten replicate plants per each treatment) was approved out 45 days for growth and 90 days for yield parameters after planting.

2.2. Growth measurements

At harvest, dry masses of roots and shoots were estimated. Leaf expanse was stately by a leaf area pattern (Licor-460, NE, USA). The number of leaves for each plant was determined.

2.3. Determination of photosynthetic pigments

Photosynthetic pigments were determined from the leaves of wheat plants by using the method of Harborne (1984) method. The extraction was restrained touching a absolute of pure 98% ethyl whiskey at three wavelengths of 452, 644 and 663 nm. The absorbance estimations were trailed with a spectrophotometer (Unico UV-2100 spectrophotometer).

2.4. Gas water relations

Transpiration rate (E), Photosynthetic rate (A), and stomatal conductance (g_s) of the entirely established fourth verdures were stately using Li-Cor, 6400XT, Lincoln, NE, USA. Gas conversation quantities were completed in the growth chamber under saturated light situations and accustomed to an strength of 450 μmol m^{-1} s^{-1}. Ten replicates were used for each treatment.

2.5. Estimation of mycorrhizal colonization

The stained pieces were positioned on photos and were detected with a optical microscope at 40 × . They were seen assigned to 6 sessions of AMF colonization (from 0 to 5, provisional on the rate of AMF construction in the root piece) and to 4 stages of AMF profusion (from A0 to A3). Mycorrhizal establishment stages of the marked roots were expected according the technique of Trouvelot et al. (1986) using the Mycocalcsoftware. This method analyzes three factors of mycorrhizal colonization as follows:-

F: Frequency of root colonization.
M: Root colonization intensity.
A: Arbuscules intensity.

2.6. Yield and yield components

Pods number, length of one pod, pods weight/ plant, weight of l00 seeds, yield ton/Fed and WUE were dogged directly after gather. Grain calculated from {yield / water applied at different level of requirements}according to Stanhill (1986). The harvest index was calculated agreeing to the following equation:

$$\text{Harvestindex} = \{\text{Economicyield}(\text{grainyield})/\text{abovegrounddrymatter} * 100$$

2.7. Biochemical analysis of yielded seeds

2.7.1. Elements content analysis

A well-known mass of the powdered quantifiable of yielded common beam seeds for each treatment was assimilated in a ingestion flask encompassing a three acid mixture (HNO_3: H_2SO_4: 60% HCl_4, with a ratio of 10:1:4; respectively). Nitrogen was dignified by Kjeldahl technique (Nelson and Sommers, 1973). Phosphorus was gritty resulting ammonium molybdate b1ue Technique . Potassium and sodium were evaluated by a flame spectrophotometer (Corning 400, UK), and calcium (Ca) and magnesium (Mg) were determined using atomic absorption by the technique of Allen (1989).

2.7.2. Estimation of vitamin B1 (Thiamine)

In this method Alkaline potassium ferricyanide was oxidized thiamine to thiochrome which was extracted in isobutyl alcohol and was measured on fluorimeter.

2.7.3. Estimation of folic acid

The folic acid was estimated in yielded seed according to (Ruengsitagoon and Hattanat, 2012).

2.7.4. Estimation of protein

A known yielded seed mass was saturated in 0.2 M borate buffer (pH 8.6), and the extracts was centrifuged at 4,300g for 15 min. The total crude protein in extracted root tissue was gritty using the technique of Bradford (1976).

2.8. Statistical analysis

A randomized widespread block strategy with ten replicates was used. All results were imperiled to statistical examination allowing to SPSS 10.0 software database. Means were equaled by the Duncan's multiple range test and arithmetical significance was gritty at 5% level.

Plate 1. Growth of common bean plants inoculated with arbuscular mycorrhizal fungi and endophytic bacteria (EB + AMF, right) and non-inoculated control (left) grown under water stress (WS2).

3. Results

3.1. Growth criteria

Generally, inoculation of mycorrhizal fungi or presoaked with endophytic bacteria significantly increased the growth response parameters like shoot and root dry weights. Number of leaves and leaf area) of common bean plants grown either normal-watered or drought stress as compared with other treatments (Table 1) and (Plate 1). The water stress treatments significantly inhibited all studied growth parameters of all treatments particularly at WS2 level. This decrease was critically offset by the combined application of mycorrhizal and endophytic bacterial treatments. Such effect was more pronounced for the treatment of WS1 with all different microorganisms studied.

3.2. Photosynthetic pigments

The results indicated in Table 2 showed the gratified of plant pigments (chlorophyll *a*, chlorophyll *b*, carotenoids and total chlorophyll) in common plant leaves was higly affected by water stress and application of microorganisms. Data clearly showed that inoculation of common bean plants with mycorrhizal fungi and endophytic bacteria in combination induced highly contents of

Table 1
Effect of arbuscular mycorrhizal fungi (AMF) and endophytic bacteria (EB) on the growth parameters of common bean plants grown under different levels of water stress.

Treatments		Shoot dry weight (g / plant)	Root dry weight (g / plant)	Number of leaves / plant	Leaf area (cm^2 / plant)
WW	**Control**	5.55 ^{g}	2.56^{f}	5.55^{df}	225.5^{f}
	AMF	7.07 ^{cd}	4.11^{c}	6.56^{d}	280.7^{de}
	EB	6.88^{e}	3.55^{d}	6.33^{de}	270.4^{d}
	AMF + EB	7.22^{d}	4.91^{b}	7.67^{c}	291.2^{c}
WS1	**Control**	5.11 ^{g}	2.11 ^{fg}	5.33^{f}	216.4 ^{g}
	AMF	8.10^{b}	4.80^{bc}	8.77^{b}	310.3^{b}
	EB	7.79^{c}	4.22^{c}	7.67^{c}	305.4^{b}
	AMF + EB	10.32^{a}	5.11^{a}	9.33^{a}	368.3^{a}
WS2	**Control**	3.83 ^{h}	1.44 ^{g}	5.00 ^{g}	197.4 ^{g}
	AMF	6.21^{f}	2.88^{e}	7.11^{e}	222.3^{f}
	EB	6.12^{f}	2.55^{f}	6.33^{e}	214.4^{e}
	AMF + EB	6.77^{e}	3.81^{d}	7.44^{d}	235.1 ^{g}
LSD $_{at\ 5\%}$		**0.51**	**0.12**	**0.61**	**6.18**

Values in each column followed by the same letter(s) are not significantly different at $P \le 0.05$), where AMF, arbuscular mycorrhizal fungi, EB, endophytic bacteria. Each value represents the mean of five replicates.

Table 2
Effect of arbuscular mycorrhizal fungi (AMF) and endophytic bacteria (EB) on photosynthetic pigments content of common bean plants grown under different levels of water stress.

Treatments		Photosynthetic pigments (μg / g fwt.)		
		Chl. "a"	Chl. "b"	Carotenoids
WW	Control	755 [cd]	435[b]	586[e]
	AMF	824[b]	504[ab]	616[d]
	EB	801[d]	476[c]	593[e]
	AMF + EB	837[b]	513[b]	708[d]
WS1	Control	710 [fg]	400[bc]	511[g]
	AMF	895[a]	511b	690[b]
	EB	830[b]	502ab	655[c]
	AMF + EM	900[a]	558a	750[a]
WS2	Control	647 [g]	353[e]	490 [h]
	AMF	792[e]	491[b]	530[f]
	EB	736[f]	467[c]	505 [g]
	AMF + EB	803[d]	499[b]	585[ef]
LSD $_{at\ 5\%}$		**16.51**	**0.12**	**11.61**

Values in each column followed by the same letter(s) are not significantly different at $P \leq 0.05$), where AMF, arbuscular mycorrhizal fungi, EB, endophytic bacteria. Each value represents the mean of five replicates.

photosynthetic pigments contents than those of other treatments particularly at WS2. Such escalations in these contents were greatly associated to the level of AMF colonization.

3.3. Water relations

In general, application of drought stress (WS2) prompted a extreme decrease in stomatal conductance and photosynthetic and transpiration rate of common bean leaves treated with or without microorganisms when compared to normal plants (Table 3). However, the rate of reduction in water relations parameters was greater in non-mycorrhizal than in mycorrhizal plants. In this connection, combined application of mycorrhizal fungi and endophytic bacteria induced significantly increased in gas exchange parametersof common bean plants grown at WS! When comparing with other treatments. Such encouragements in water status factors were accompanying to the grade of the AMF infection.

3.4. Mycorrhizal colonization

Mycorrhizal colonization parameters were articulated as colonization frequency of the stained segments (F), intensity of cortical colonization (M) and frequency of arbuscules in roots (A) Table 4. The results presented that the AMF establishment levels were significantly reduced by increasing the water stress level at WS2 while significantly increased at WS1 particularly at the interaction between AMF and endophytic bacteria Thus, it can be concluded that under water stress (WS1) the endophytic bacteria fungi was able to increase the root colonized by mycorrhizal fungi at all treatments. These stimulations in mycorrhizal colonization levels were marked at WS2.

3.5. Yield and yield components

The results recorded in Table 5 and Plate 2 showed that the application of drought stress had a significant decreased on the plant yield of grain number, number and weight of pods and pod length of common bean plants grown with or without biological agents compared with control plants. In general, soaking of common bean seeds or inoculation with mycorrhizal fungi alone or in combination occasioned in a noteworthy rise in the studied yield parameters of common bean plants as likened with other treatments. These stimulations in yield components were pronounced in plants grown under WS1 level (Plate 3).

3.6. Quality parameters of common bean yielded seeds

3.6.1. Nutrient contents

In general, Nutritional elements of common bean seeds; N, P, K, Ca and Mg of AMF common bean plants was knowingly developed than that in non-AMF plants developed either in well-watered or drought stressed conditions (Table 6), and the effect was more pronounced at WS1. Such upsurges in these contents were related to the grade of the AMF Colonization. Furthermore, mixed application of mycorrhizal fungi and endophytic bacteria revealed a significant increase in the nutritional elements of common bean yielded seeds when compared with other treatments. Such increases were highly remarked when the plant grown under WS1.

3.6.2. Protein, fiber and folic acid contents

The mean values of crude protein, crude fiber and folic acid in seeds of common bean as influenced by water stress, different microorganisms and their interaction are presented in Table 7. The co inoculation of common bean seeds with the different microorganisms under all water stress levels significantly increased the average values of crude protein, crude fiber, folic acid and Vitamin B1 in yielded seeds of common bean than those obtained for the control plants under the same water stress. In this connection, dual application of mycorrhizal fungi and endophytic bacteria particularly under WS1 caused significantly increased in crude protein and fiber and folic acid of studied plant when comparing with other treatments.

3.7. Water use efficiency (WUS)

Water use efficiency (WUE) is a measurable amount of in what way ample biomass or harvest is formed per quantity of water castoff. It is a bubbly functional factor for agronomy, particularly in zones with a incomplete convenience of water. It is also central in a better sympathetic of drought tolerance and water stress opposition. Result illustrated in Fig. 1 revealed that the biological technology like mycorrhizal fungi and endophytic bacteria alone or in combination play a critical role for increasing the WUS in common bean plants grown beneath unlike levels of water stress. Among all studied treatments, mixed application of mycorrhizal fungi and endophytic bacteria induced a remarkable increase in WUS of common bean plants grown in well watered or drought stressed conditions. This effect was more pronounced at WS1 level of water stress. Such upturns in WUS relaxed were related to the grade of the AMF infection.

Table 3
Effect of arbuscular mycorrhizal fungi (AMF) and endophytic bacteria (EB) on Photosynthetic rate (*P*N), transpiration rate (*E*) and stomatal conductance (*gs*) in leaves of common bean plants grown under different levels of water stress.

Treatments		Gas water exchange parameters		
		PN (μmol m^{-2} s^{-1})	*E* (μmol m^{-2} s^{-1})	*gs* (μmol m^{-2} s^{-1})
WW	**Control**	6.55^{d}	4.021^{f}	0.115^{e}
	AMF	7.99^{c}	4.355^{e}	0.166^{c}
	EB	7.44^{c}	4.233^{e}	0.150^{c}
	AMF + EB	8.68^{ab}	4.989^{d}	0.198^{b}
WS1	**Control**	6.15^{d}	4.001^{f}	0.101^{e}
	AMF	10.61^{b}	6.556^{b}	0.192^{b}
	EB	9.11^{ab}	5.995^{c}	0.188^{b}
	AMF + EM	12.13^{a}	7.115^{a}	0.225^{a}
WS2	**Control**	5.00^{f}	3.080 ^{h}	0.090^{f}
	AMF	5.68^{e}	3.410^{gh}	0.146^{d}
	EB	5.55e	3.325 ^{h}	0.132^{d}
	AMF + EB	6.13^{d}	3.558 $_{g}$	0.165^{c}
LSD $_{at\ 5\%}$		**1.55**	**13.12**	**0.185**

Values in each column followed by the same letter(s) are not significantly different at $P \leq 0.05$), where AMF, arbuscular mycorrhizal fungi, EB, endophytic bacteria. Each value represents the mean of five replicates.

Table 4
Frequency of mycorrhizal colonization (F%), intensity of root colonization (M%) and arbuscular frequency (A%) of common bean plants grown under different levels of water stress.

Treatments		*Mycorrhizal levels*		
		F%	*M%*	*A%*
WW	**Control**	0.0^{e}	0.0 ^{e}	0.0^{d}
	AMF	77.00^{c}	33.32^{c}	25.41^{c}
	EB	0.0 ^{e}	0.0 ^{e}	0.0 ^{d}
	AMF + EB	81.00^{bc}	54.26^{b}	32.54 ^{h}
WS1	**Control**	0.0^{e}	0.0 ^{e}	0.0 ^{d}
	AMF	86.00^{b}	65.54^{a}	33.58^{b}
	EB	0.0 ^{e}	0.0 ^{e}	0.0 ^{d}
	AMF + EM	90.00^{a}	66.53^{a}	48.56^{a}
WS2	**Control**	0.0 ^{e}	0.0 ^{e}	0.0 ^{d}
	AMF	67.67^{c}	29.86^{d}	21.31^{d}
	EB	0.0 ^{e}	0.0 ^{e}	0.0 ^{d}
	AMF + EB	44.33^{d}	32.46^{c}	25.61^{c}
LSD $_{at\ 5\%}$		**11.71**	**13.12**	**5.61**

Values in each column followed by the same letter(s) are not significantly different at $P \leq 0.05$), where AMF, arbuscular mycorrhizal fungi, EB, endophytic bacteria. Each value represents the mean of five replicates.

Table 5
Effect of arbuscular mycorrhizal fungi (AMF) and endophytic bacteria (EB) on the yield components of common bean plants grown under different levels of water stress.

Treatments		No. of pods/plant	Pod length (cm /plant)	Weight of 100 seed(g)	Weight of pods (g / plant)	Yield (Ton/ Fed
WW	**Control**	10.67^{de}	06.55^{e}	20.64^{d}	50.54^{de}	22.98 ^{s}
	AMF	18.00^{bc}	08.32^{c}	30.41^{c}	55.51^{d}	30.36 ^{k}
	EB	17.05^{c}	07.55 cd	28.45 ^{cd}	50.65^{de}	27.60^{n}
	AMF + EB	22.33^{b}	09.26^{bc}	35.54^{b}	66.63^{c}	33.13 ^{h}
WS1	**Control**	10.02^{de}	06.11^{e}	17.55^{de}	35.45^{f}	19.30^{w}
	AMF	22.15^{b}	11.54^{b}	40.22^{b}	85.68^{b}	36.83^{d}
	EB	20.11^{bc}	10.92^{bc}	36.63^{b}	80.11^{b}	34.96^{f}
	AMF + EB	28.00^{a}	13.53^{a}	48.56^{a}	99.89^{a}	39.62^{a}
WS2	**Control**	07.05^{e}	05.12^{ef0}	15.10^{ef}	35.11^{f}	18.41^{x}
	AMF	12.97d	07.86 ^{cd}	22.31^{d}	43.55^{e}	23.90^{r}
	EB	12.00^{d}	07.15^{d}	20.08^{d}	40.88^{e}	21.14^{u}
	AMF + EB	15.66 ^{cd}	08.61^{c}	28.31 ^{cd}	58.12^{d}	28.49 ^{m}
LSD $_{at\ 5\%}$		**5.11**	**2.55**	**7.61**	**10.18**	**4.82**

Values in each column followed by the same letter(s) are not significantly different at $P \leq 0.05$), where AMF, arbuscular mycorrhizal fungi, EB, endophytic bacteria. Each value represents the mean of five replicates.

4. Discussion

Water stress is reflected as individual of the gravest abiotic stresses that restrictions plant growth and decreases yield making in several regions universal (Calvo-Polanco et al., 2016). Water stress often cradles inferior soil water approaching, inducing cell dehydration, finally ensuing in avoiding cell enlargement and dissection, leaf extent, stem elongation, root detonation, concerned stomatal changes, plant water, nutrient uptake, and WUE (Kaushai and Wani, 2016). In the current study, AM injection considerably augmented all the assessed growth and yield restrictions of common bean plants grown either in well-watered or drought

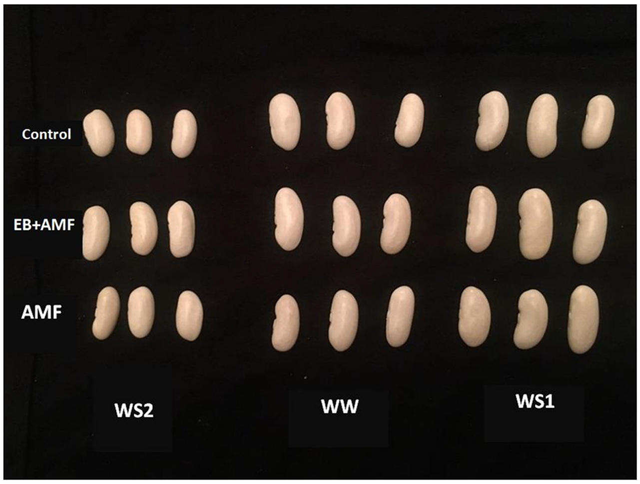

Plate 2. Effect of arbuscular mycorrhizal fungi and endophytic bacteria (EB + AMF) on the fruiting stage of common bean plants grown under different levels of water stress (WW, WS1 and WS2).

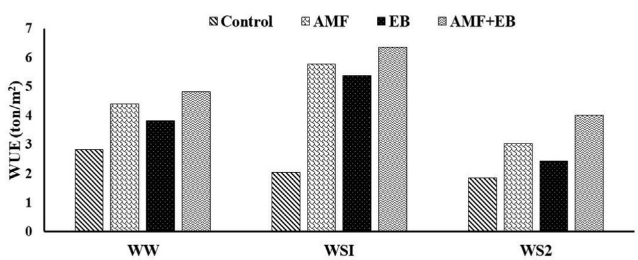

Plate 3. Effect of arbuscular mycorrhizal fungi (AMF) alone and endophytic bacteria (EB) in combination on seed yield of common bean plants grown under different levels of water stress (WW, WS1 and WS2).

stress conditions comparing to non-mycorrhizal plants. Such escalations in development limitations of plants caused from the AMF inoculation and were straight relative to the own level of the mycorrhizal infection. The degree of development in reaction to the mycorrhizal settlement was more noticeable in drought stressed soils. Enriched growth of mycorrhizal plants is often related to improved indispensable nutrition due to hyphal networks leading to plants. This outline of reply to the mycorrhizal inoculation in little phosphorus soils is completely reliable by preceding trainings (Liu et al., 2003).

Mutual occupation of common bean plants with mycorrhizal fungus and endophytic bacteria meaningfully increased growth and yield components of common bean plants as compared with other treatments. The grade of growth in reply to the AMF inoculation and endophytic bacteria was added noticeable in water stressed soils. In this connection, arbuscular mycorrhizal fungi colonized host roots uses the extraradical mycelium to explore a larger volume of soil, and transfer nutrients from soil to the plants more efficiently and increasing photosynthesis, which reflected on the improvement of plant growth and enrichment of fruit nutrition and increasing of seed yield (Sturz et al., 2000; Abdel-Fattah et al., 2014). In addition, Jagnow et al. (1991) described that bacteria, an operative quantity of Auxin and cytokines assembly are the origin of leaf area, augmented levels of root hairs, absorption more nutrients from the soil and upsurge be preoccupation and offers the circumstances for plant growth. Furthermore, enhanced progress and development of AMF plants particularly in traumatic situation is partially accredited to healthier water station of the leaf matters (Colla et al., 2008), upgraded capacities to engross nutrients from soil, higher root hydraulic conductivity and extreme photosynthetic rates of mycorrhizal plants (Yang et al., 2014).

Additionally, upgraded progress and growth of AMF plants specially in demanding location is partly qualified to healthier water grade of the leaf tissues (Colla et al., 2008), value-added aptitudes to grip nutrients from soil, higher root hydraulic conductivity and high photosynthetic rates of mycorrhizal plants (Yang et al., 2014).

It is apparent after the current study that *gs*, *PN*, and *E* were ominously upper in the AMF than in the non-AMF plants full-grown in soil by or water stress. The escalations were associated to the grade of mycorrhizal inoculation. These statistics are in treaty with those established by Auge et al. (2007). Abdel-Fattah et al. (2013) informed that increased E and gs in AM plants under amply irrigated and drought conditions. A higher *E* in leaves of the mycorrhizal and endophytic bacterial plants would then be relentless with the higher rates of the *gs* which often complement the mycorrhizal symbiosis, and are supposed to be needed to source the carbon requirements of the fungal symbiotic (Abdel-Fattah et al., 2016). A noteworthy upsurge in P and its transport by hyphae have been detected or figured in occurrences in which the AM cooperation has also pretentious the stomatal conduct (Abdel-Fattah et al., 2013; ; Yang et al., 2014).

The higher WUE in mycorrhizal and EB combination treatment than other water treatments plants grown under WS1 conditions).

Table 6
Effect of arbuscular mycorrhizal fungi (AMF) and endophytic bacteria (EB) on concentration of nitrogen, phosphorus, potassium, calcium and magnesium in yielded seeds of common bean grown under different levels of water stress.

Treatments		N%	P%	K%	Ca%	Mg%
WW	**Control**	2.13^{p}	0.275^{p}	1.78^{r}	1.65^{r}	1.16^{q}
	AMF	2.70 ^{h}	0.344 ^{h}	2.36^{j}	2.32^{i}	1.79 ^{h}
	EB	2.61^{i}	0.334^{i}	2.23 ^{k}	2.24^{jk}	1.73^{i}
	AMF + EB	2.80 ^{fg}	0.356^{f}	2.52 ^{h}	2.49^{f}	1.97^{e}
WS1	**Control**	2.05^{q}	0.261^{q}	1.67 ^{s}	1.54 ^{s}	1.08^{r}
	AMF	2.97^{c}	0.379^{c}	2.77^{d}	2.72^{c}	2.11^{d}
	EB	2.88^{de}	0.366^{e}	2.61^{f}	2.60^{e}	2.02^{e}
	AMF + EB	**3.13^{a}**	**0.400^{a}**	**2.99^{a}**	**2.87^{a}**	**2.29^{a}**
WS2	**Control**	1.96^{r}	0.199^{r}	1.49 ^{t}	1.43 ^{t}	0.97 ^{s}
	AMF	2.36 ^{l}	0.306 ^{m}	2.01^{o}	1.88^{n}	1.38^{n}
	EB	2.24^{n}	0.297^{n}	1.93^{pq}	1.77^{p}	1.26^{p}
	AMF + EMB	2.52^{jk}	0.324^{jk}	2.17 ^{l}	2.09 ^{l}	1.59 ^{k}
LSD $_{at\ 5\%}$		**0.05**	**0.005**	**0.04**	**0.05**	**0.04**

Values in each column followed by the same letter(s) are not significantly different at $P \leq 0.05$), where AMF, arbuscular mycorrhizal fungi, EB, endophytic bacteria. Each value represents the mean of five replicates.

Table 7
Effect of arbuscular mycorrhizal fungi (AMF) and endophytic bacteria (EB) on total protein, crude fiber and folic acid in yielded seeds of common bean plants grown under different levels of water stress.

Treatments		CurdeProtienμg/g))	Crude Fiber %	Folic acid (mg/100 g)
WW	Control	1331 [g]	4.88[e]	144.5[c]
	AMF	1685[d]	5.99[c]	155.7[c]
	EB EM + EndoEB	1654[d]	5.28[d]	150.2[c]
	AMF + EB	1735[c]	6.29[b]	177.3[ab]
WS1	Control	1279 [h]	4.90[e]	130.2[d]
	AMF	1854[b]	6.00[b]	210.3[b]
	EB	1821[b]	5.88[c]	205.6[b]
	AMF + EB	1954[a]	6.99[a]	239.8[a]
WS2	Control	1227 [h]	4.11[f]	120.1 [cd]
	AMF	1475[f]	4.91[e]	140.5[bc]
	EB	1400[f]	4.77[e]	135.4 [cd]
	AMF + EB	1773[e]	5.54 [cd]	159.6c
LSD at 5%		**80.55**	**0.33**	**15.6**

Values in each column followed by the same letter(s) are not significantly different at $P \leq 0.05$), where AMF, arbuscular mycorrhizal fungi, EB, endophytic bacteria. Each value represents the mean of five replicates.

Fig. 1. Effect of arbuscular mycorrhizal fungi and endophytic bacteria (EB + AMF) on water use efficiency (WUS) of common bean plants grown under different levels of water stress (WW, WS1 and WS2).

These results described that mycorrhizal fungi canister impact water-uptake facility and WUE in host plants. AMF augmented the capacity of root to absorb soil moisture that improved water conductivity has been attributed to area increase for water uptake produced by AMF hyphae in soil (Auge, 2001; Zhang et al., 2011). An supplementary, preservation of tissue water place of plants, fungal connotation also welfares the plants by increasing their water use efficiency (WUE). For example in maize, Zhu et al. (2011) have exposed that the value-added WUE and qualified this to amplified water and mineral uptake from the soil prominent to healthier development of plants and hence, augmented water use efficiency. Increased WUE of AM seedlings was also detected by Yang et al. (2014) in black locust seedlings. So, the offered material obviously showed the protagonist of AMF in training tension acceptance to the plants besides cultivating their WUE as glowing.

Our results indicated that, increasing in nutrient guts in seeds yield in reply to the mycorrhizal and EM possessions were extremely allied with the level of combination infection. Mycorrhizal and EM shared bean plants had greater contents of nutrients than those of other treatments plants particularly at WS1. These results are confirmed by Khalil (2013) who stated that nutrients were engaged up by the hyphae to the plant, which principal to a actual effective enlistment and uptake of phosphate, nitrogen and other elements that were ecstatic to the plant.

It is evidence from the present study that that total carbohydrates, protein content, total soluble suger, vitamin C, folice acid and crude fiber in the dry seeds of inoculated plants with mycorrhizal fungi and EB (*Bacillus amyloliquefaciens*) are significantly higher than other treatments particularly at WS1, in connection, total crude protein and total carbohydrates of root mines of common bean plants were generally abridged with increasing of water stress level. These outcomes are in agreement with the results of (Moussa and Abdel-Aziz, 2008) who stated that increasing water stress can cause rapid damage to plant cells membrane. Also, Water stress affects plant growth and productivity as it causes various physiological and biochemical changes including hormonal and nourishing disparity, ion injuriousness, and susceptibility to diseases (Nadeem et al., 2014).

Seed yield quality was significantly affected by irrigation treatments, the effect of biofertilizers treatment and its interaction with irrigation on seed yield was significant. Arbuscular mycorrhizal fungi or endophytic bacteria alone or in combination allow more efficiency nutrients or increase nutrients availability can afford bearable solutions for present and future agricultural practices. These results are in harmony with those obtained by Abd El-Malak (2005); Saleh et al. (2007) and Wu et al. (2013) who stated that, beneficial microorganisms are involved primarily in safety against biotic and abiotic stresses, resulting often, in refining host plant growth and environment health.

5. Conclusion

Data obtained in the present investigation concluded that mutual injection of arbuscular mycorrhizal fungus (*G. mosseae*) and endophytic bacteria (*Bacillus amyloliquefaciens*) meaningfully relieved the detrimental effects of drought on common bean plants grown in drought soil via, stimulating gas-exchange, growth and yield parameters, improving water use efficiency and enhancing some metabolic activities in yielded seeds of common bean plants. Though, these welfares in reply to the mycorrhizal and bacterial inoculation usually higher at second level of water stress in this experiment, suggesting that AMF and endophytic bacteria as a biological technique could be used as ant-stress bio-agents.

Author contributions

Salem Al-Amri have several publications in international journals like Photosynthetica, Microbiological Research, Australian journal of Botany, Phyton, Saudi Journal of Biological Sciences. These papers enrolled in list of publications for Associate professor

Promotion in 2014 from Shaqra University. Salem Al-Amri is interested in field of physiology of higher plants particularly grown under stress conditions.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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