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The effect of drought stress and plant growth promoting rhizobacteria on agro-morphological characters of lemon balm (*Melissa officinalis* L.)

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Extended abstract

Introduction

Lemon Balm (*Melissa officinalis* L.) as an aromatic medicinal plant belongs to the genus mentha and has a variety of uses. Nowadays, due to the increasing popularity of medicinal plants, the area under these plants' cultivation continue to increase. However, problems such as environmental stresses limit the development of these plants' cultivation. Drought stress is one of the most important factors limiting the growth and yield of agricultural products around the world. The use of growth-promoting rhizosphere bacteria (PGPR) as a biofertilizer with the aim of reducing the damage caused by environmental stresses is considered as one of the new solutions in sustainable agriculture in arid and semi-arid regions of the world. In this regard, this study was designed and conducted to investigate the effect of plant growth promoting rhizobacteria on agro-morphological characters of Lemon Balm under water deficit stress

Materials and methods

This experiment was done during 2018-2019 growing season at the research field of the faculty of agricultural, Shahrekord University as split-plot factorial in a Randomized Complete Block Design with three replications. water deficit in three levels (full irrigation, 75 and 50 present of full irrigation) and inoculation with PGPRs at five levels (Control (No bacterial inoculation), Inoculation with Azospirillum lipoferum, Bacillus sp. strain A, Bacillus amyloliquefaciens and Streptomyces rimosus) considered as main and sub factors, respectively. The amount of irrigation water was calculated using plant water requirement. Leaf area was measured with Digimizer software. After harvesting, first the plant height was measured and then the number of main and sub-branches was counted and the leaf dry weight, stem dry weight and biological yield were determined. SAS and Excel softwares implemented for statistical analysis and the means were compared using LSD test.

Results and discussion

The results showed that the effect of bacteria and drought stress on plant height, number of main branches, number of sub-branches, leaf dry weight, stem dry weight, leaf area, essential oil percent, biological yield and essential oil yield were significant. With increasing stress intensity, all studied traits

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were decreased. So that by applying 50% of full irrigation, plant height, leaf area and biological yield were reduced by 39.4%, 67.4% and 60.5%, respectively, compared to full irrigation treatment. While inoculation of plants with PGPRs caused a significant increase in these traits compared to the control treatment (No bacterial inoculation). The interaction effect of the studied treatments on the number of main branches, number of sub-branches, stem dry weight, leaf area, essential oil percent, biological yield and essential oil yield was significant. At full irrigation treatment, the highest biological yield was observed in inoculated treatments of Azospirillum lipoferum and Bacillus amyloliquefaciens, which increased biological yield by 58.2% and 53.09%, respectively, compared to the control. At 75 and 50% of full irrigation treatments, the highest biological yield and essential oil yield were observed in inoculated treatments of Azospirillum lipoferum and Bacillus amyloliquefaciens. In all the studied treatments, increasing the intensity of drought stress reduced the biological and essential oil yield, but inoculated bacteria were able to increase the biological and essential oil yield compared to the bacterial control treatments.

Conclusion

The results of this study showed that increasing water deficit stress causing significant reduction of all studied traits. However, the use of bacteria reduced the effects of stress and increased these traits compared to non-inoculated at all water deficit stress levels. Also among bacterial treatments, Bacillus amyloliquefaciens, A. lipoferum and S. rimosus had the most effect on stress improvement.

***Keywords*:** Biofertilizers, Essential oil, Irrigation management, Medicinal plants, Sustainable agriculture

Table 1. Means comparison for effects of drought and bacterial inoculation on plant height, number of main and sub branche, leaf dry weight, stem dry weight, leaf area, essential oil, biological yield and essential oil yield

Treatment	Plant height	Number of main branches	Number of sub-branches	Leaf dry weight	Stem dry weight
	cm			------------- g/m^2-----------------	
Drought stress					
Full Irrigation	47.38^a	12.40^a	101.75^a	326.18^a	178^a
75% Full Irrigation	38.01^b	8.93^b	47.58^b	230.09^b	114.84^b
50% Full Irrigation	28.72^c	5.94^c	26.02^c	138.92^c	60.38^c
LSD (5%)	2.52	0.93	11.41	59.95	32.71
Bacterial inoculation					
Control	33.32^c	7.42^d	38.77^c	177.21^c	85.17^c
Bacillus amyoliquefaciens	40.34^a	10.31^a	67.88^a	255.63^a	134.68^a
***Bacillus* sp. Strain A**	37.92^b	8.51^c	57.93^b	219.26^b	106.97^b
Streptomyces rimosus	38.58^{ab}	9.28^b	62.45^{ab}	242.51^a	124.59^a
Azospirillum lipoferum	40.01^{ab}	9.93^{ab}	65.22^a	264.03^a	137.26^a
LSD (5%)	2.12	.75	6.45	21.68	13.36

Table 1. Continued

Treatment	Leaf area	Biological yield	Essential oil percent	Essential oil yield
	cm^2	g/m^2	%	g/m^2
Drought stress				
Full Irrigation	13116.9^a	504.18^a	0.25^b	131.69^a
75% Full Irrigation	7473.7^b	344.93^b	0.28^a	99.99^b
50% Full Irrigation	4273.2^c	199.30^c	0.21^c	42.91^c
LSD (5%)	1660.3	91.81	0.027	21.84
Bacterial Inoculation				
Control	5665.8^c	262.39^d	0.21^c	54.64^c
Bacillus amyloliquefaciens	10136.5^a	390.31^{ab}	0.28^a	111.58^a
***Bacillus* sp. Strain A**	7923.7^b	326.23^c	0.24^b	81.24^b
Streptomyces rimosus	7472.7^b	367.10^b	0.24^b	91.63^b
Azospirillum lipoferum	10240.9^a	401.31^a	0.28^a	118.58^a
LSD (5%)	1485.9	33.25	0.023	12.72

In each column, means followed with at least one similar letter(s) don't have significant differences at the 5% probability level based on LSD test

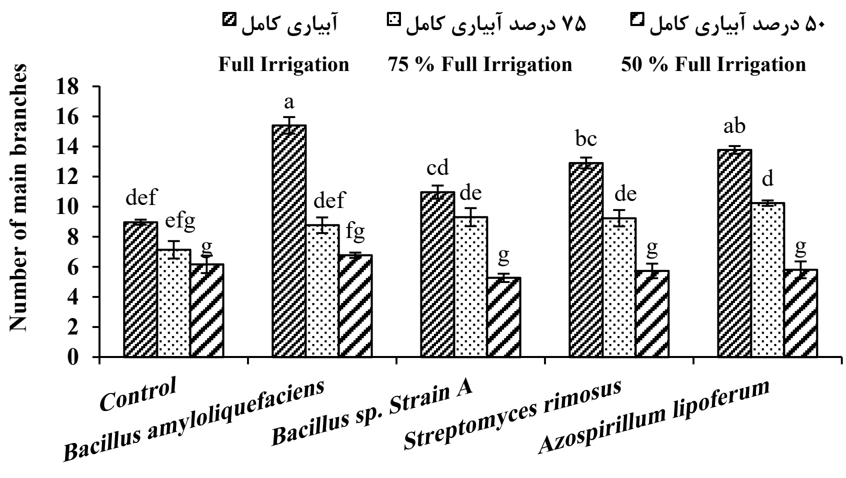

Fig. 1. Interaction effect of drought stress and bacterial inoculation on number of main branches. The vertical lines on each column are the standard deviation.

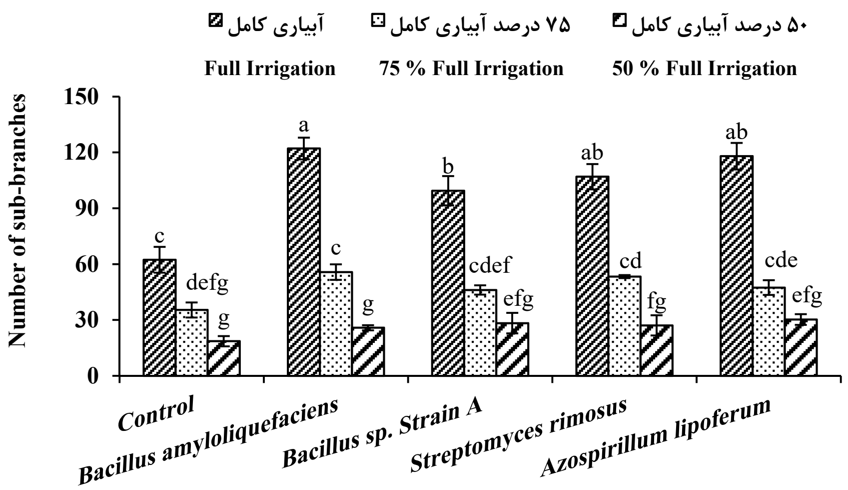

Fig. 2. Interaction effect of drought stress and bacterial inoculation on number of sub-branches. The vertical lines on each column are the standard deviation.

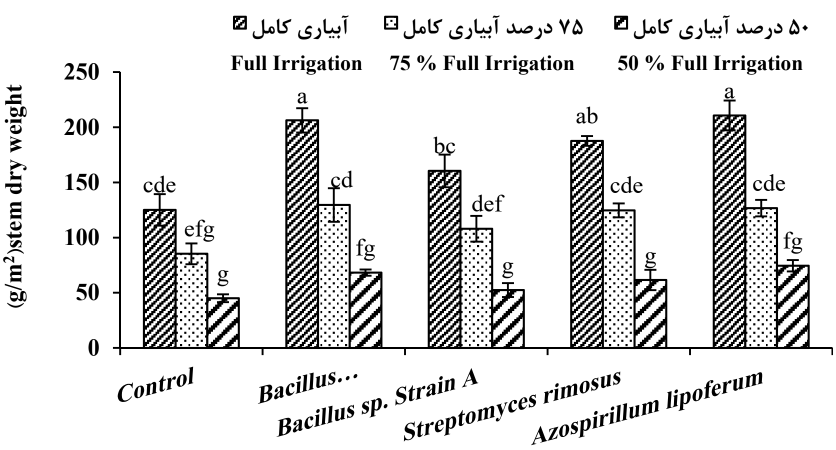

Fig. 3. Interaction effect of drought stress and bacterial inoculation on stem dry weight. The vertical lines on each column are the standard deviation

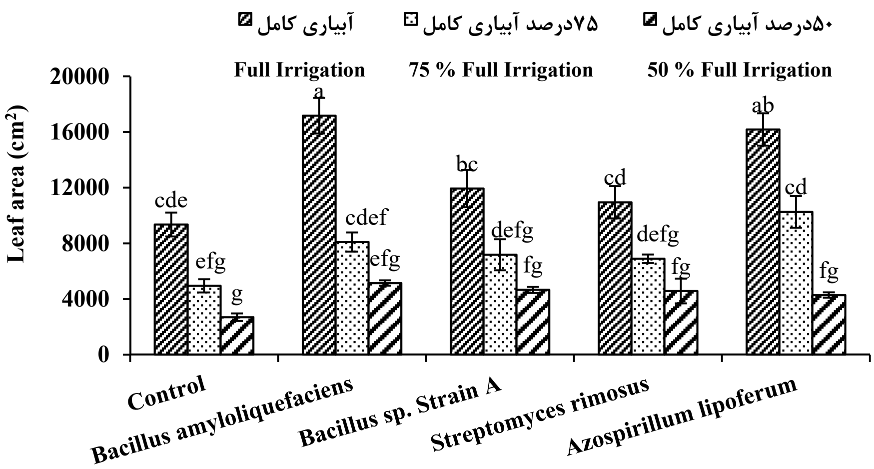

Fig. 4. Interaction effect of drought stress and bacterial inoculation on leaf area. The vertical lines on each column are the standard deviation

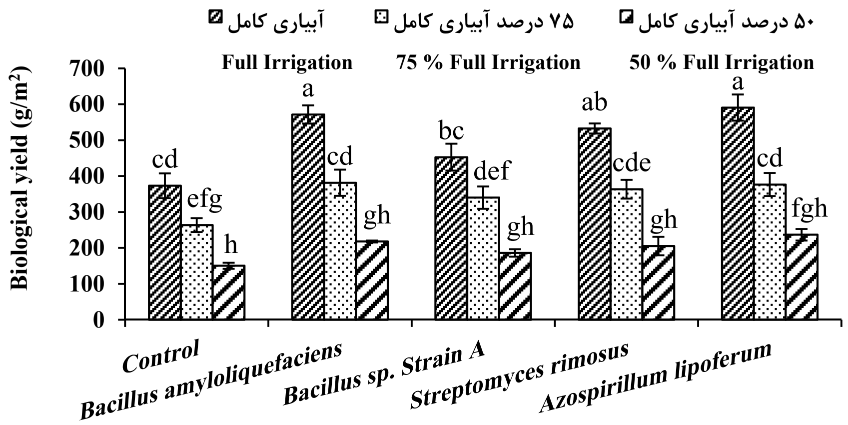

Fig. 5. Interaction effect of drought stress and bacterial inoculation on biological yield. The vertical lines on each column are the standard deviation.

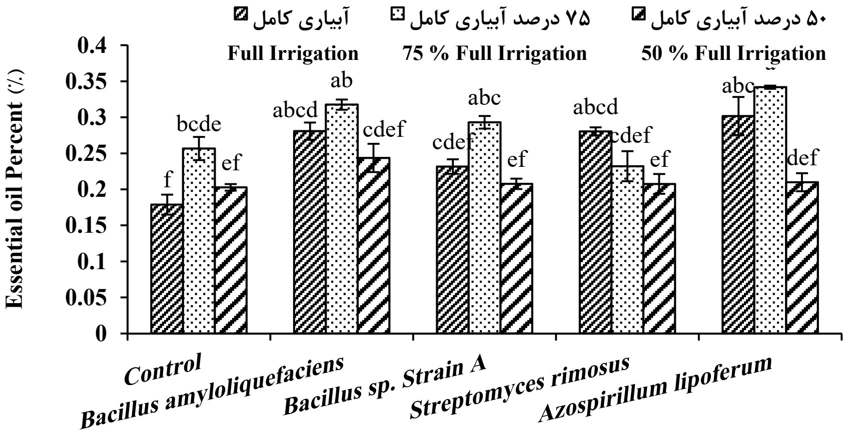

Fig. 6. Interaction effect of drought stress and bacterial inoculation on Essential oil Percent. The vertical lines on each column are the standard deviation.

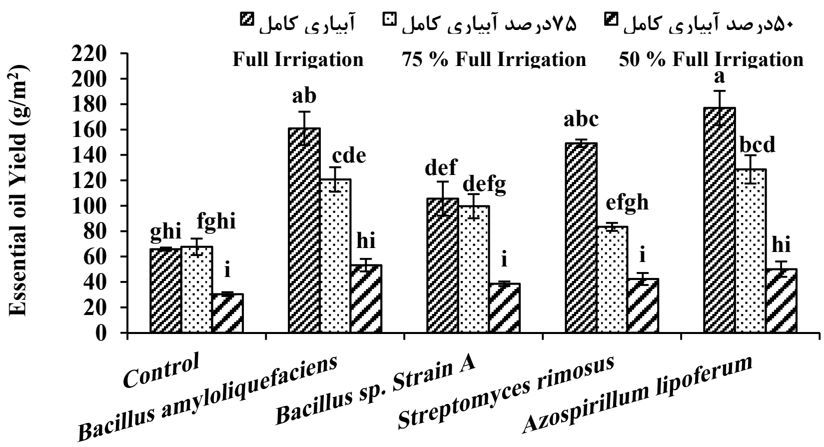

Fig. 7. Interaction effect of drought stress and bacterial inoculation on Essential oil yield. The vertical lines on each column are the standard deviation