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Original article

Interaction of mycorrhizal coexistence and foliar application of iron and zinc on some quantitative and qualitative characteristics of mung bean under different irrigation regimes

M. Abbasi[1], A. Maleki[2*], M. Mirzaei Heydari[2], M. Rostaminya[3]

1. PhD Student of Plant Physiology, Department of Agronomy, College of Agriculture, Islamic Azad University, Ilam Branch, Ilam, Iran
2. Assistant Professor of Agronomy, Department of Agronomy and Plant Breeding, College of Agriculture, Islamic Azad University of Ilam Branch, Ilam, Iran
3. Assistant Professor, Department of Soil Science, Faculty of Agriculture, Ilam University, Ilam, Iran

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Extended abstract

Introduction

Drought stress is one of the main causes of plant growth limitation that has affected most of the world's agricultural lands. Due to the location of Iran in the almost arid and semi-arid region of the world and also the lack of moisture in such areas, there is a possibility of water shortage stress in most of the growth stages of plants. Mung bean cultivation is severely affected by drought stress, while micronutrients such as iron and zinc nanoparticles can reduce the effects of drought stress. Therefore, this study was conducted to investigate the effect of mycorrhizal and nano-iron and zinc fertilizer coexistence on quantitative and qualitative performance and absorption of mung bean elements under different irrigation regimes.

Material and methods

This test was performed in 2017 in two regions of Mehran and Malekshahi. The experiment was performed as a split-factor in the form of a randomized complete block design with three replications. The main factors included irrigation regimes at three levels: no stress, moderate stress, and severe dehydration stress, which were evaporated at 60, 90, and 120 mm, respectively, at these levels. The sub-factor includes nano-fertilizers at four levels (no fertilizers, zinc nano-chelates, iron nano-chelates and the combined application of zinc and iron nano-chelates) with the application of Arbuscolar mycorrhizal fungi on two levels (control and inoculation with fungi). Took. Statistical analysis was performed using SAS software.

Results and discussion

The effect of irrigation, nano-fertilizer, mycorrhiza and their dual effects on biological yield and mung bean seed yield were significant. The double effect (irrigation × mycorrhiza) and the triple interaction effect on grain yield were significant. The yield of mung bean seeds in the plants of Malekshahi region was higher than the plants of Mehran region. The use of iron and zinc nano-fertilizers increased the yield of mung bean seeds in both Mehran and Malekshahi areas. In the Malekshahi area, iron and zinc nanocomposites combined and increased grain yield at different irrigation levels. The highest grain yield was obtained in the treatment of moderate dehydration stress and combined consumption of iron and zinc nano fertilizers in Malekshahi region with 1184 kg ha^{-1}, which was not significantly different from

*Correspondent author: Abbas Maleki; E-Mail: maleki97@yahoo.com.

non-stress. The use of zinc nano-fertilizer and iron + zinc nano-fertilizer increased the amount of mung bean protein (27.38%). Iron nanocode (26.9%) did not have a significant effect on mung bean protein content compared to zinc nano fertilizer and control treatment.

Conclusion

Drought stress led to reduced yields and mung bean yield components, but the use of iron and zinc nanocomposites and mycorrhizal fungi, both individually and in combination, improved grain yield and yield components. Also, the use of iron and zinc nanocodes and mycorrhizal fungi separately and together led to improved grain quality and increased grain protein content.In general, the results of this study showed that drought stress led to a decrease in yield and yield components of mung bean, but the use of iron and zinc nanofertilizers and mycorrhizal fungus, either alone or in combination, led to improved yield and grain yield components.

***Keywords*:** Coexistence, Iron Nanocode, Mung, Mycorrhiza

Table 1. Physical and chemical properties of used soil (0-30 cm soil depth)

Area	Siol texture	EC	pH	OC	P available	K available	N	Fe	Zn
		dSm^{-1}		%	------- $mg.kg^{-1}$ -------		%	------- $mg.kg^{-1}$ -------	
Mehran	Loam	0.38	7.51	1.16	10	380	0.06	1.7	3.7
Malekshahi	Clay loam	0.87	7.02	1.17	12	280	0.08	1.9	4

Table 2. Combined analysis of variance of the effect of irrigation, mycorrhizal fungi and chelate on mung bean grain yield components

S.O.V	df	Number of pods per plant	seeds per pod	1000 seed weight	Biologic yeild	Seed yeild
Place (P)	1	7.66 *	42.88 ^{ns}	248.1*	559911 ^{ns}	29578 ^{ns}
Place (Rep)	4	0.90	40.99	29.7	1331267	5314
Irigation (I)	2	222.1 **	246.1**	1165.8**	16639197**	396648**
P × I	2	1.35 ^{ns}	2.59 ^{ns}	3.69 ^{ns}	115 ^{ns}	201 ^{ns}
Main error	8	3.30	3.92	95.46	782325	1658
Mycorrhiza (M)	1	1.638 *	0.31 ^{ns}	127.3*	630532*	12243*
Chelate (C)	3	89.93 **	33.22**	267.7**	1768910**	306793**
M × I	2	0.03 ^{ns}	5.11 *	0.05 ^{ns}	17327 ^{ns}	9052*
C × I	6	16.07**	3.04 ^{ns}	11.3 ^{ns}	995585**	7313 *
M × C	3	0.025 ^{ns}	3.40 ^{ns}	9.56 ^{ns}	19085 ^{ns}	3018 ^{ns}
P × M	1	0.0002 ^{ns}	3.09 ^{ns}	0.01 ^{ns}	252 ^{ns}	5.123 ^{ns}
P × C	3	0.038 ^{ns}	3.66 ^{ns}	5.18 ^{ns}	1502 ^{ns}	1.14 ^{ns}
I × M × Ce	6	0.016 ^{ns}	2.87 ^{ns}	0.09 ^{ns}	10146 ^{ns}	7537*
P × I × M	2	0.0006 ^{ns}	3.27	0.03 ^{ns}	1183 ^{ns}	3.12^{ns}
P × I × C	6	0.609 ^{ns}	3.31 *	3.22 ^{ns}	1974 ^{ns}	2.12 ^{ns}
P × M × C	3	0.0016 ^{ns}	3.09 ^{ns}	0.15 ^{ns}	114 ^{ns}	2.10 ^{ns}
P × I × M × C	6	0.0004 ^{ns}	3.12 ^{ns}	0.15 ^{ns}	783 ^{ns}	5.56 ^{ns}
Sub-error	84	0.390	1.46	29.93	137948	2873
CV (%)	-	*7.73*	*12.93*	*10.49*	*8.82*	*5.62*

* and **: significantly at the level of five and one percent probability, respectively; ns: non- significant

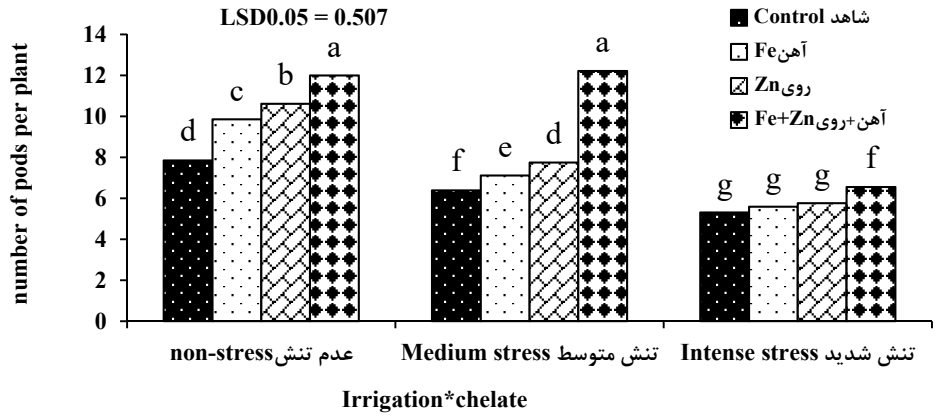


Fig. 1. The effect of chelate on the number of pods per mung bean plant in Mehran and Malekshahi. Columns with similar letters in each, show non- significant difference according to Duncan multiple range tests at 5% level

Table 3. Comparison of the mean effect of location, irrigation, mycorrhizal fungus and chelate on yield and yield components of mung bean

	Number of pods per plant	1000 seed weight	Biological yield
Place		g	kg/ha
Malekshahi	8.31 [a]	53.47 [a]	4271 [a]
Mehran	7.85 [b]	50.85 [b]	4146 [a]
LSD (0.05)	*0.4392*	*2.5228*	*534*
Irrigation			
Non-stress	10.07 [a]	57.06 [a]	4541 [a]
Medium stress	8.37 [b]	52.23 [b]	4556 [a]
Severe stress	5.80 [c]	47.20 [c]	3528 [b]
LSD (0.05)	*0.856*	*4.599*	*416*
Mychoriza fungi			
Control	7.97 [b]	51.22 [b]	4142 [b]
Mychoriza	8.18 [a]	53.10 [a]	4274 [a]
LSD (0.05)	*0.207*	*1.8133*	*123*
Chelate			
Control	6.52 [d]	48.91 [c]	4490 [a]
Fe	7.52 [c]	51.64 [b]	4044 [c]
Zn	8.04 [b]	52.58 [b]	4279 [b]
Fe+Zn	10.25 [a]	55.52 [a]	4019 [c]
LSD (0.05)	*0.2927*	*2.5643*	*174*

The means with common letters in each column, based on the test of the least significant difference at the level of five percent probability, there is no significant difference

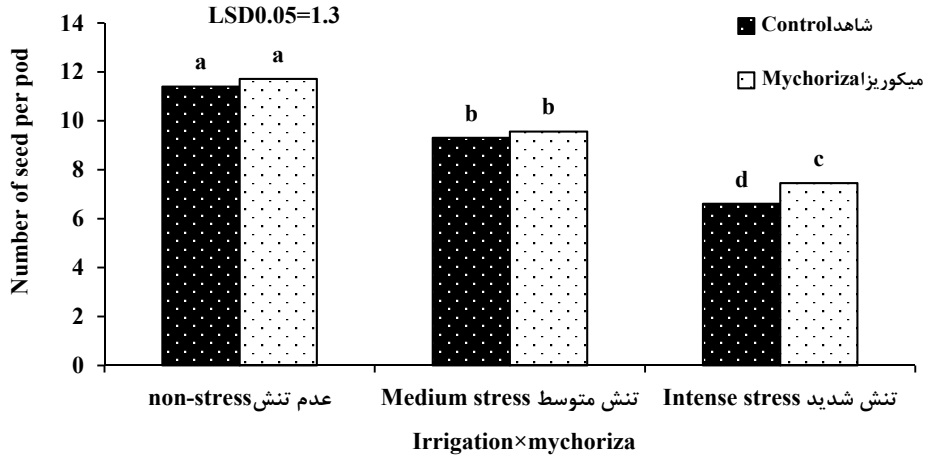
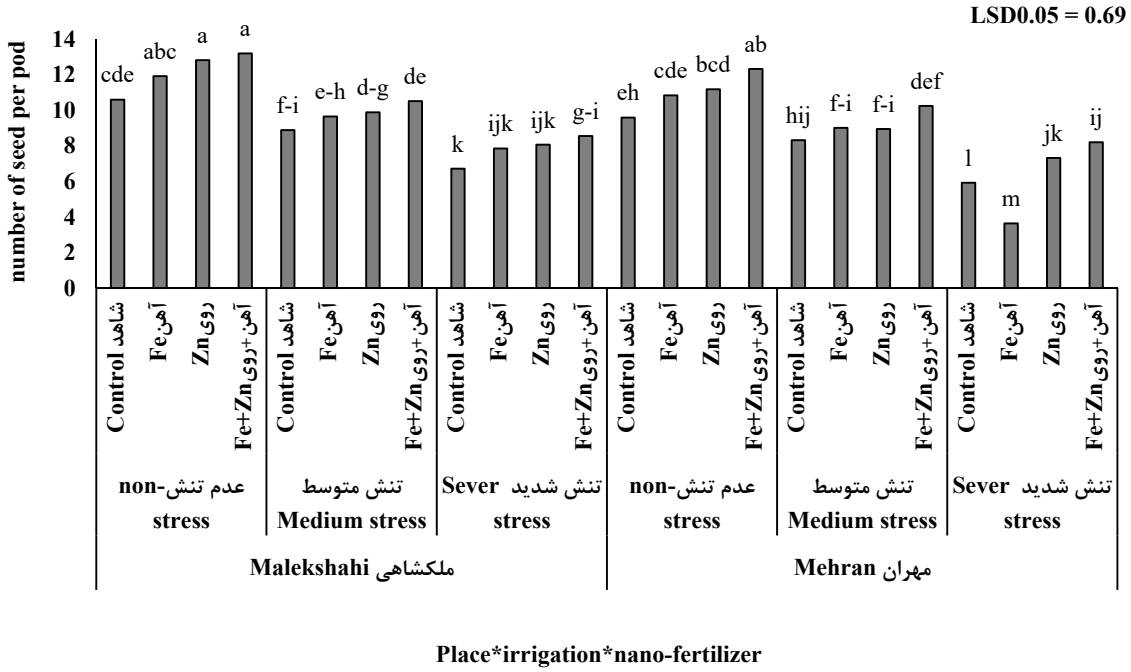


Fig. 2. The effect of mycorrhizal fungus on the number of seeds in mung bean pods at different levels of irrigation. Columns with similar letters in each, show non- significant difference according to Duncan multiple range tests at 5% level



Place*irrigation*nano-fertilizer

Fig. 3. The effect of chelate on the number of grains per pod at different levels of irrigation in Mehran and Malekshahi . Columns with similar letters in each, show non- significant difference according to Duncan multiple range tests at 5% level

Table 4. Comparison of the mean effect of irrigation and chelate on biological yield

Irrigation	Chelate	Biological yield (kg/ha)
non-stress	Control	4634 abcd
	Fe	4688 abc
	Zn	4715 ab
	Fe+Zn	4928 a
Medium stress	Control	4230 e
	Fe	4430 bcde
	Zn	4398 cde
	Fe+Zn	4361 de
Sever stress	Control	4145 e
	Fe	3342 fg
	Zn	3488 f
	Fe+Zn	3139 g
LSD (0.05)		301

The means with common letters in each column, based on the test of the least significant difference at the level of five percent probability, there is no significant difference

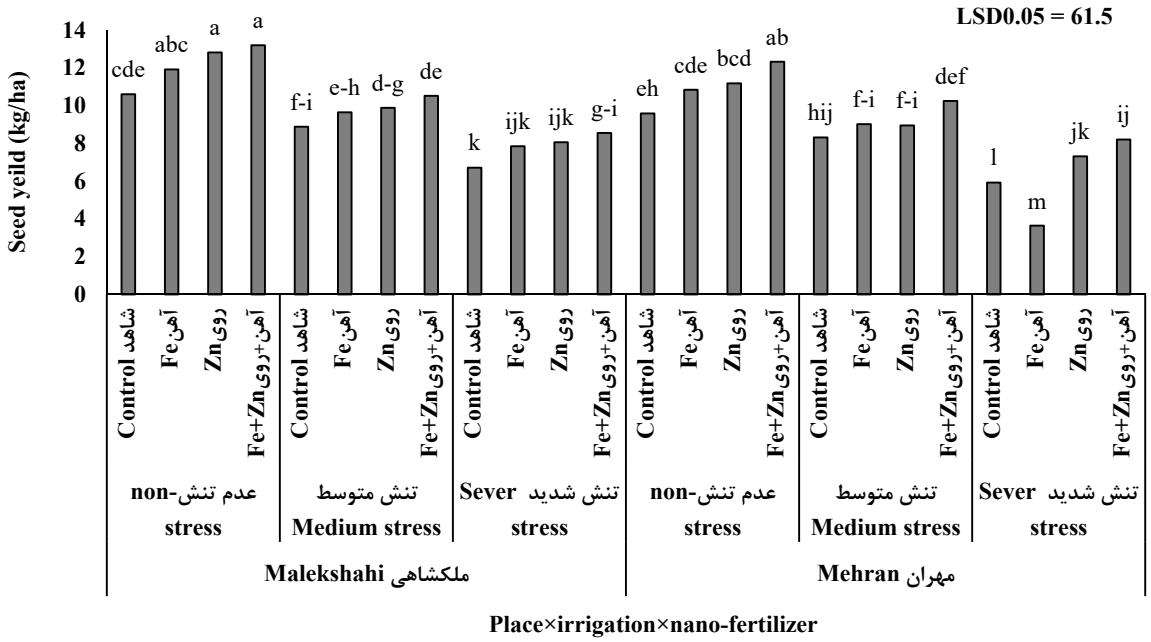


Fig. 4. The effect of chelate and mycorrhizal fungi on mung bean grain yield at different levels of irrigation. Columns with similar letters in each, show non- significant difference according to Duncan multiple range tests at 5% level

Table 5. Combined analysis of variance of the effect of irrigation, mycorrhiza and chelate on protein and colonization

S.O.V	df	Seed protein	Protein yeild	Root colonization
Place (P)	1	11.639 ^{ns}	9.73 ^{ns}	82.53 ^{ns}
Place (Rep)	4	103.1 **	100.8	20.86
Irigation (I)	2	504.2	41.3 **	2276.8 **
P × I	2	10.19 ^{ns}	70.8 ^{ns}	37.66 ^{ns}
Main error	8	10.37	3.04	6.78
Mycorrhiza (M)	1	6.059 ^{ns}	10.4 ^{ns}	107.1 **
Chelate (C)	3	61.07 *	424.7 **	81.27 **
M × I	2	1.575 ^{ns}	5.04 ^{ns}	2.59 ^{ns}
C × I	6	2.746 ^{ns}	5.58 ^{ns}	2.78 ^{ns}
M × C	3	2.041 ^{ns}	2.82 ^{ns}	4.07 ^{ns}
P × M	1	0.352 ^{ns}	0.01 ^{ns}	114.8 **
P × C	3	0.355 ^{ns}	0.02 ^{ns}	33.44 *
I × M × C	6	2.435 ^{ns}	5.22 ^{ns}	1.82 ^{ns}
P × I × M	2	0.045 ^{ns}	0.02 ^{ns}	27.91 ^{ns}
P × I × C	6	0.081 ^{ns}	0.03 ^{ns}	4.06 ^{ns}
P × M × C	3	0.129 ^{ns}	0.03 ^{ns}	4.14 ^{ns}
P × I × M × C	6	0.148 ^{ns}	0.026 ^{ns}	3.52 ^{ns}
Sub-error	84	18.913	16.95	11.79
CV (%)	-	*11.8*	*9.6*	*8.9*

* and **: significantly at the level of five and one percent probability, respectively; ns: non-significant

Table 6. Comparison of mean effects of location, irrigation, mycorrhizal fungus and chelate on mung bean seed protein

	Seed protein	protein yield
Irrigation	(%)	(kg/ha)
Non-stress	23.59 ^{c}	25.86 ^{a}
Medium stress	26.48 ^{b}	24.86 ^{b}
Sever stress	30.07 ^{a}	24.01 ^{c}
LSD (0.05)	*1.516*	*0.8212*
Chelate		
Control	25.30 ^{b}	20.98 ^{d}
Fe	26.19 ^{b}	23.34 ^{c}
Zn	27.01 ^{ab}	26.56 ^{b}
Fe+Zn	28.37 ^{a}	28.75 ^{a}
LSD (0.05)	*2.0385*	*1.9298*

The means with common letters in each column, based on the test of the least significant difference at the level of five percent probability, there is no significant difference

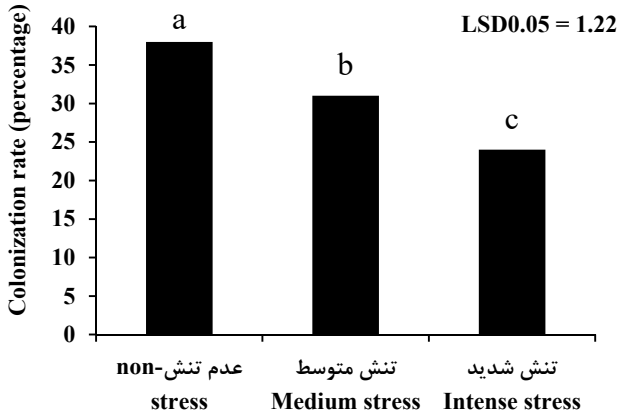


Fig. 5. The effect of irrigation on the rate of mung bean root colonization. Columns with similar letters in each, show non- significant difference according to Duncan multiple range tests at 5%

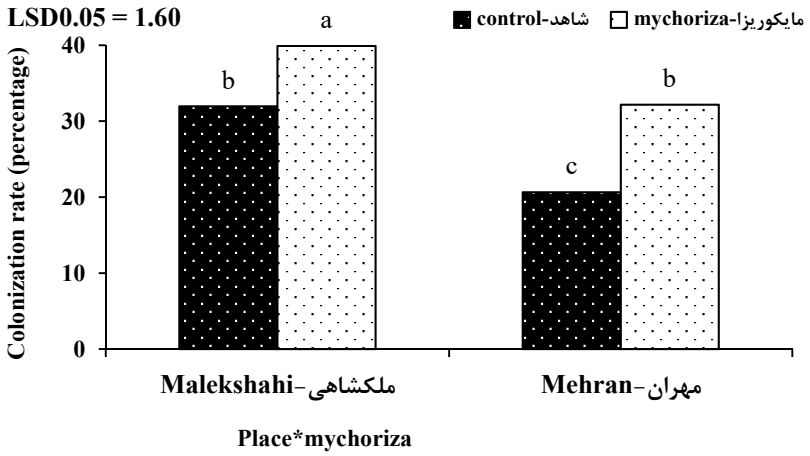


Fig. 6. Effect of mycorrhizal fungus on the rate of mung bean root colonization in Malekshahi and Mehran. Columns with similar letters in each, show non- significant difference according to Duncan multiple range tests at 5% level

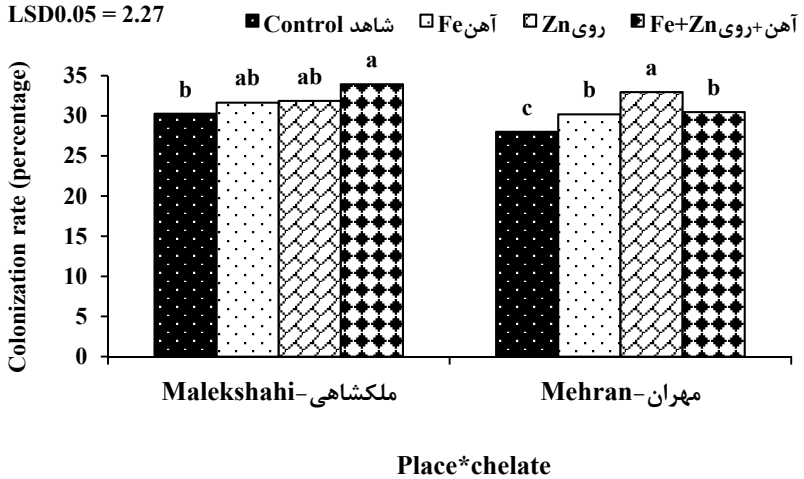


Fig. 7. The effect of chelate on the rate of mung bean root colonization in Malekshahi and Mehran. Columns with similar letters in each, show non- significant difference according to Duncan multiple range tests at 5% level.

Table 7. Combined analysis of variance of the effects of irrigation, mycorrhizal fungi and chelate on the concentration of elements

S.O.V	df	N	P	K	Fe	Zn	Mn
Place (P)	1	0.11 ^{ns}	10.4 ^{ns}	6.912 ^{ns}	6.938 ^{ns}	0.561 ^{ns}	0.195 ^{ns}
Place (Rep)	4	1.907	27.1 **	22.46	38.8 **	31.90	46.202
Irigation (I)	2	3.92 **	767.1	632.4 **	5512^{ns}	226.9 *	369.3**
P × I	2	0.12 ^{ns}	0.33 ^{ns}	0.082 ^{ns}	0.130 ^{ns}	0.031 ^{ns}	0.0091 ^{ns}
Main error	8	2.41	22.9 ^{ns}	1.529	64.6	39.405	16.1002
Mycorrhiza (M)	1	0.005 ^{ns}	5.43 *	7.053 *	4.12 ^{ns}	0.995 ^{ns}	3.29 ^{ns}
Chelate (C)	3	4.61**	61.9 **	95.35 **	770.1 **	1453**	66.12**
M × I	2	0.22 ^{ns}	0.20 ^{ns}	3.987 ^{ns}	0.419 ^{ns}	0.150 ^{ns}	0.1677 ^{ns}
C × I	6	0.19 ^{ns}	1.55 ^{ns}	28.69 **	11.35 ^{ns}	0.992 ^{ns}	1.855 ^{ns}
M × C	3	0.61 ^{ns}	0.68 ^{ns}	1.292 ^{ns}	0.504 ^{ns}	0.079 ^{ns}	0.183 ^{ns}
P × M	1	0.006^{ns}	0.06 ^{ns}	0.421 ^{ns}	0.512 ^{ns}	0.034 ^{ns}	0.010 ^{ns}
P × C	3	0.16 ^{ns}	0.005 ^{ns}	0.421 ^{ns}	4.002 ^{ns}	0.026 ^{ns}	0.201 ^{ns}
I × M × C	6	0.15 ^{ns}	0.19 ^{ns}	0.987 ^{ns}	0.183 ^{ns}	0.065 ^{ns}	0.010 ^{ns}
P × I × M	2	0.001 ^{ns}	0.003 ^{ns}	0.031 ^{ns}	0.497 ^{ns}	0.028 ^{ns}	0.0004 ^{ns}
P × I × C	6	0.14 ^{ns}	0.001 ^{ns}	0.031 ^{ns}	1.289 ^{ns}	0.025 ^{ns}	0.0731 ^{ns}
P × M × C	3	0.14 ^{ns}	0.004 ^{ns}	0.421 ^{ns}	0.185 ^{ns}	0.027 ^{ns}	0.0005 ^{ns}
P × I × M × C	6	0.115 ^{ns}	0.001 ^{ns}	0.031 ^{ns}	0.174 ^{ns}	0.026 ^{ns}	0.0002 ^{ns}
Sub-error	84	0.435	1.338	1.750	43.59	10.338	2.3774
CV (%)	-	16.42	10.18	10.70	10.33	10.67	11.28

*and **: significantly at the level of five and one percent probability, respectively; ns: non- significant

Table 8. Comparison of the mean effect of location, irrigation, mycorrhizal fungus and chelate on mung bean agronomic traits

	N	P	K
Irrigation	%	----------mg/kg----------	
non-stress	3.13 ^{c}	15.34 ^{a}	15.375 ^{a}
Medium stress	4.06 ^{b}	11.39 ^{b}	13.384 ^{b}
Sever stress	5.86 ^{a}	7.35 ^{c}	8.333 ^{c}
LSD (0.05)	0.7313	2.2546	0.582
Mychoriza fungi			
Control	3.84 ^{a}	11.17 ^{b}	^{b}12.14
Mychoriza	3.89 ^{a}	11.56 ^{a}	^{a}12.59
LSD (0.05)	0.2187	0.3834	0.4385
Chelate			
Control	3.65 ^{c}	9.56 ^{c}	10.23 ^{c}
Fe	3.82 ^{b}	11.49 ^{b}	12.60 ^{b}
Zn	4.14 ^{b}	11.68 ^{b}	12.43 ^{b}
Fe+Zn	4.46 ^{a}	12.71 ^{a}	14.19 ^{a}
LSD (0.05)	0.3093	0.5422	0.6201

The means with common letters in each column, based on the test of the least significant difference at the level of five percent probability, there is no significant difference

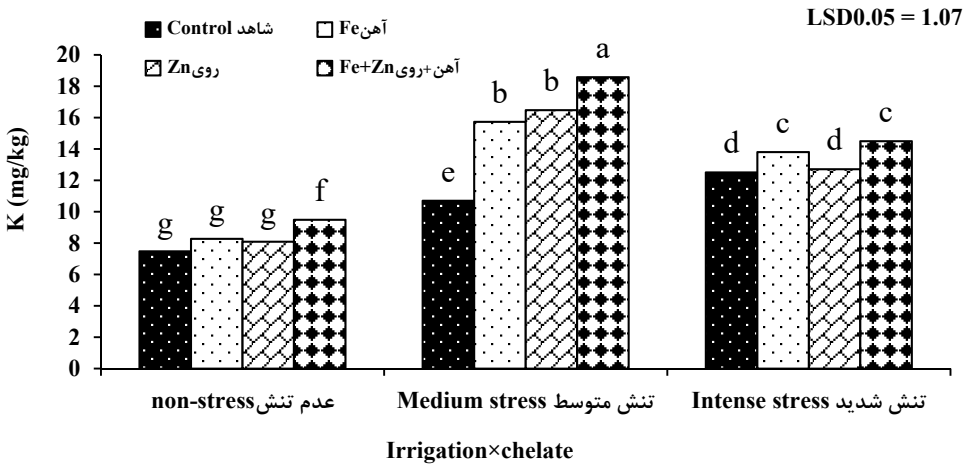


Fig. 8. The effect of chelate on mung bean seed potassium concentration at different irrigation levels. Columns with similar letters in each, show non- significant difference according to Duncan multiple range tests at 5% level

Table 9. Comparison of the mean effect of irrigation and chelate on the concentration of mung bean micro-grain elements

Irrigation	Fe	Zn	Mn
	----------mg/kg----------		
non-stress	75.15 a	32.28 a	16.75 a
Medium stress	b 62.74	30.20 ab	12.877 b
Sever stress	53.81 c	27.93 b	11.376 b
LSD (0.05)	3.7838	2.9548	1.8887
chelate			
Control	58.70 c	25.38 b	11.99 c
Fe	61.75 a	35.10 a	13.23 b
Zn	69.23 a	23.95 b	14.38 a
Fe+Zn	65.93 b	36.11 a	15.07 a
LSD (0.05)	3.0949	1.5071	0.7227

The means with common letters in each column, based on the test of the least significant difference at the level of five percent probability, there is no significant difference