University of Birjand

تنشهای محیطی در علوم زراعی
Environmental Stresses In Crop Sciences
Vol. 14, No. 3, pp. 703-718
Fall 2021
http://dx.doi.org/10.22077/escs.2020.3197.1816

Original article

Effect of foliar application of iron, zinc and manganese nano-chelate on some quantitative and qualitative characteristics of soybean (*Glycine max* L.) under water deficit stress

M.S. Vaghar[1*], S. Sayfzadeh[2], H.R. Zakerin[3], S. Kobraee[4], S.A.R. Valadabadi[2]

1. Assistant professor, Department of Agriculture, Ghasre Shirin Branch, Islamic Azad University, Ghasre Shirin, Iran
2. Associate Professor, Department of Agriculture, Takestan Branch, Islamic Azad University, Takestan, Iran
3. Assistant professor, Department of Agriculture, Takestan Branch, Islamic Azad University, Takestan, Iran
4. Assistant professor, Department of Agriculture, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran

Received 27 February 2020; Accepted 10 June 2020

Extended abstract

Introduction

The country's food security and economy are certainly dependent on agricultural production. Today, however, water scarcity causes the agricultural product facing a serious threat. Drought stress disrupts the balance of uptake of micronutrients and also the transfer of nutrients from roots to plant shoots. In addition, deficiency of micronutrients can reduce the resistance of soybean to drought, as the life cycle and production of vegetable crops suffer from irreparable problems, it is therefore essential to maintain food security and provide plant protein in the human food basket. Due to the importance and role of micronutrients in reducing the effects of drought stress, this experiment was conducted to investigate the effect of foliar application of Fe, Zn, and Mn fertilizers on soybean in irrigation interruption at different stages of plant productivity.

Materials and methods

This experiment was conducted as split plot in a randomized complete block design with three replications on soybean cultivar M9 at Agricultural Research Farm of Islamic Azad University, Kermanshah Branch during two consecutive years (2016-2017). The climate of the area is the semi-arid cold to temperate. According to the meteorological statistics, the mean annual precipitation and temperature in the region were 480.7 mm and 15.8 °C, respectively. Fertilizer recommendation was applied on the basis of soil test results (50 kg urea and 100 kg superphosphate). Irrigation treatments were applied at four levels including complete irrigation, an interruption irrigation turn at flowering stage, podding start, seed filling period as main plots and foliar application was performed at eight levels including foliar application with Fe, Zn, Mn, Fe+Zn, Fe+Mn, Zn+Mn, Fe+Zn+Mn Nano-chelates and distilled water (control) in sub-plots. In order to foliar application of micronutrients, chemical fertilizers with the brand name of Fe (9%), Zn (12%) and Mn (12%) nano chelate in powder form that was completely soluble in water with 6.5 pH which was prepared by Khezra Company. Each experimental plot consisted of 6 rows that are 6 m length and the distance among rows was 50 cm. The seeds were

*Correspondent author Mohammad Saeed Vaghar; E-Mail: ms.vaghar@yahoo.com

impregnated with a symbiotic bacterium (Rhizobium japonicum) and were cultured manually at the depth of 5 cm and the distance of 5 cm on May 10, 2015 and 2016. Nanochelate foliar spraying was performed at a concentration of three in one thousand at two time points, stage V4 (formation of the fourth leaf on the stem) and one week after spraying the first time. The studied traits were seed yield, biomass yield, harvest index, number of pods per plant, number of pods per pod, number of seeds per plant, 1000-seed weight, oil percentage, oil yield, protein percentage and protein yield of soybean.

Result

The results of combined analysis of variance showed that the main effects of drought stress, foliar application, and interaction between irrigation and foliar application on the studied traits was significant. The interaction of drought stress at podding stage and non-foliar application of nano chelate further reduced 1000-seed weight (30%), seed yield (34.9%), biomass yield (29.5%) and harvest index (7.6%) rather than control treatment in complete irrigation. In contrast Fe+Zn foliar application increased these traits 22.9%, 61.6% 46.5% and 10% respectively and was superior to other treatments. Oil loss percentage was more severe due to irrigation interruption at seed filling stage, and the lowest oil percentage (17.47) was obtained from combination of irrigation interruption at seed filling stage and non-foliar application and the most related to combination of complete irrigation and Zn+Mn foliar application (23.73). While the highest seed protein (39.57%) was obtained from irrigation interruption at seed filling stage and Zn+Mn foliar application. Overall, the results showed that the effect of drought stress in podding and seed filling stages on soybean yield and yield components was higher. Fe+Zn foliar application had the highest seed yield by better adjusting the stress effect. Treatments of Zn+Mn and Fe+Mn were the next priorities.

Conclusions

Overall, the results showed that foliar application with each of the elements Fe, Zn and Mn is an applied method to increase the micronutrients content in plants and yield and yield components of the plant can be increased by reducing the effect of drought, under water deficit conditions, combined use of these elements was more effective. The combined treatments of complete irrigation and Zn+Mn foliar application had the highest seed yield with an average of 3704.6 kg.ha^{-1}.

***Keywords*:** Drought stress, Micro nutrients, Seed oil, Seed protein, Seed yield

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

Year	Sand	Clay	Silt	Organic matter	N	Fe	Zn	Mn	P	K	pH	Soil texture
	……..…..…..(%)……..……					……..…..(mg.kg^{-1})……..…..…						
2015	14	40	46	2.3	0.19	6.4	0.72	4.2	9.8	539	7.5	Silty-clay
2016	12	41	47	2.2	0.15	5.9	0.81	4.1	10.1	499	7.4	Silty-clay

Table 2. Variance analysis of soybean quantitative traits in different irrigation treatments and Fe, Zn and Mn nano-chelate foliar application (Mean squares)

Sources of variation	df	Seed yield	Biological yield	Harvest index	Pods / plant	Seeds / pod	seeds / plant
Year (Y)	1	4826.5^{ns}	35361.3^{ns}	9.48^{ns}	42.62^{ns}	13.68^{ns}	105.95^{ns}
Replication×Y	4	115578.3	41930.1	2.73	15.32	6.71	96.18
Irrigation (I)	3	10669955**	914975.5**	105.73**	208.96**	242.44**	2800.57**
Y×I	3	8679.7.7^{ns}	13719.7^{ns}	1.25^{ns}	1.49^{ns}	0.24^{ns}	17.12^{ns}
Error	12	767.1	12793.6	4.08	7.83	4.29	35.01
Foliar application(F)	7	2168121**	611894.7**	8.62^{ns}	82.51**	92.78**	872.14**
Y×F	7	18692.8^{ns}	5245.2^{ns}	0.53^{ns}	4.15^{ns}	2.96^{ns}	5.40^{ns}
I×F	21	56371.5**	17685.1**	12.06**	0.68^{ns}	2.65^{ns}	20.86**
Y×I×F	21	18634.8^{ns}	3071.2^{ns}	2.25^{ns}	0.59^{ns}	2.34^{ns}	5.93^{ns}
Total error	112	73084.6	354599.1	7.74	8.65	5.40	52.61
C.V (%)	-	10.6	12.7	6.64	10.36	10.08	10.57

ns, * and **: Non-significant and significant at 5% and 1% probability levels, respectively

Table 3. Mean comparison of soybean quantitative traits in different irrigation treatments and Fe, Zn and Mn nano-chelate foliar application

Irrigation	Foliar application	Seed yield	Biological yield	Harvest Index	Seeds/plant
		---------- Kg.ha^{-1} ----------		%	
Complete irrigation	Control	2491.2 ^{e}	6079.6 ^{f}	40.97 ^{d}	66.57 ^{f}
	Fe	3211.1 ^{c}	7484.3 ^{d}	42.90 ^{bc}	79.78 ^{c}
	Zn	3215.4 ^{c}	7456.7 ^{d}	43.12 ^{b}	78.40 ^{d}
	Mn	3436.1 ^{bc}	7775.4 ^{c}	43.19 ^{b}	82.02 ^{b}
	Fe+Z	3600.9 ^{b}	8194.4 ^{ab}	43.94 ^{ab}	83.68 ^{ab}
	Fe+Mn	3222.5 ^{c}	7494.3 ^{d}	42.99 ^{bc}	81.41 ^{bc}
	Zn+Mn	3704.6 ^{a}	8358.4 ^{a}	44.32 ^{a}	84.00 ^{a}
	Fe+Zn+Mn	2795.7 ^{d}	6588.4 ^{e}	42.42 ^{c}	75.41^{e}
	Mean	*3209.7*	*7428.9*	*42.98*	*78.91*
Water deficit at the flowering stage	Control	2097.5 ^{e}	5374.7 ^{f}	39.32 ^{e}	47.15 ^{e}
	Fe	2487.4 ^{c}	5912.3 ^{cd}	42.07 ^{c}	58.76 ^{d}
	Zn	2407.7 ^{cd}	5810.5 ^{d}	41.42 ^{cd}	59.80 ^{d}
	Mn	2562.9 ^{bc}	5829.3 ^{d}	43.96 ^{a}	63.69 ^{c}
	Fe+Z	2885.8 ^{a}	6817.5 ^{a}	42.32 ^{c}	68.58 ^{b}
	Fe+Mn	2638.5 ^{b}	6432.4 ^{c}	41.02 ^{cd}	70.40 ^{ab}
	Zn+Mn	2879.4 ^{a}	6691.2 ^{b}	43.03 ^{b}	71.38 ^{a}
	Fe+Zn+Mn	2307.7 ^{d}	5655.8 ^{e}	40.08 ^{d}	63.99 ^{c}
	Mean	*2533.4*	*6065.5*	*41.65*	*62.97*
Water deficit at the pod set stage	Control	1622.1 ^{e}	4283.9 ^{p}	37.86 ^{d}	51.90 ^{e}
	Fe	2112.3 ^{c}	5279.4 ^{d}	40.01 ^{bc}	61.18 ^{c}
	Zn	2141.7 ^{c}	5321.1 ^{cd}	40.24 ^{bc}	60.44 ^{d}
	Mn	2218.3 ^{bc}	5446.2 ^{c}	40.72 ^{b}	63.86 ^{b}
	Fe+Z	2613.8 ^{a}	6276.5 ^{a}	41.64 ^{a}	67.51 ^{a}
	Fe+Mn	2459.9 ^{b}	6106.2 ^{ab}	40.28 ^{bc}	66.47 ^{ab}
	Zn+Mn	2485.3 ^{b}	6056.6 ^{b}	41.02 ^{ab}	67.54 ^{a}
	Fe+Zn+Mn	1914.7 ^{d}	4660.5 ^{e}	41.08 ^{ab}	62.45 ^{bc}
	Mean	*2196.01*	*5428.8*	*40.35*	*62.66*
Water deficit at the seed filling period stage	Control	1762.1 ^{e}	4381.9 ^{f}	39.21 ^{e}	56.99 ^{d}
	Fe	1995.3 ^{d}	4957.1 ^{e}	41.08 ^{c}	69.14 ^{c}
	Zn	2200.2 ^{c}	5211.8 ^{d}	42.22 ^{b}	68.04 ^{c}
	Mn	2413.5 ^{b}	5768.5 ^{c}	41.83 ^{bc}	72.03 ^{b}
	Fe+Z	2655.7 ^{a}	6179.2 ^{a}	42.97 ^{a}	75.14 ^{a}
	Fe+Mn	2576.3 ^{ab}	5993.2 ^{b}	42.95 ^{a}	74.86 ^{ab}
	Zn+Mn	2583.6 ^{ab}	6099.1 ^{ab}	42.26 ^{b}	72.95 ^{b}
	Fe+Zn+Mn	2080.6 ^{d}	5129.9 ^{e}	40.55 ^{d}	70.76 ^{bc}
	Mean	*2283.4*	*5465.1*	*41.63*	*69.99*

Means followed by the same letters are not significantly different by the Duncan test 5% probability level

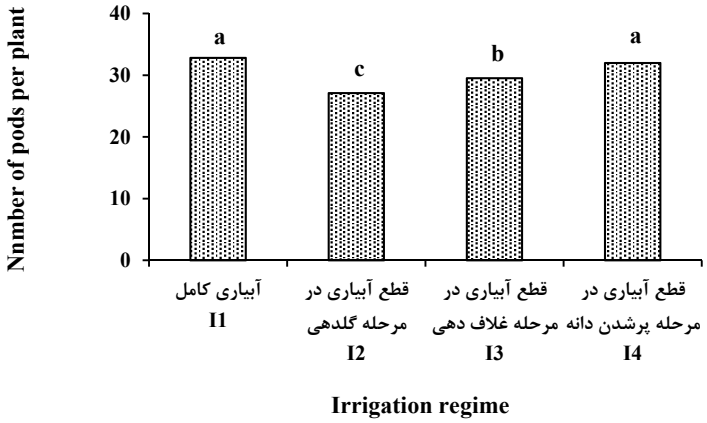

Fig. 1. The mean of number of pods per plant of soybean under complete irrigation and drought stress condition. I1= Complete irrigation, I2= Water deficit at the flowering stage, I3= Water deficit at the pod set stage, I4= Water deficit at the seed filling period

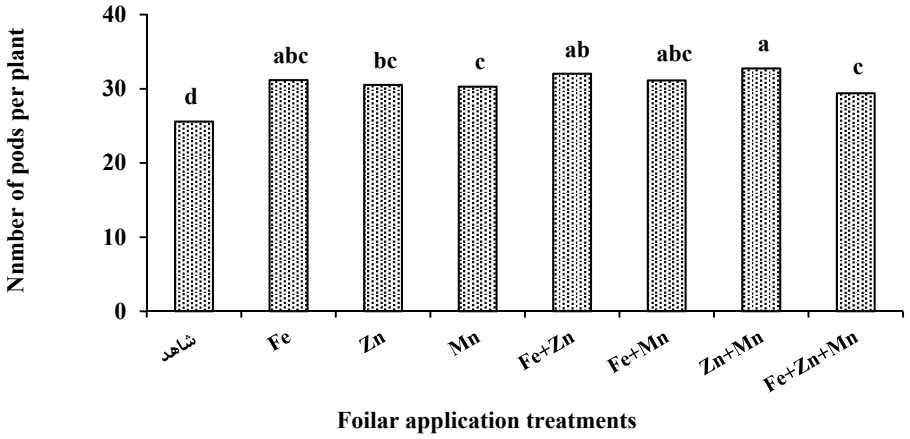

Fig. 2. Effect of foliar application of iron, zinc and manganese nano-chelate on the number of pods per plant of soybean

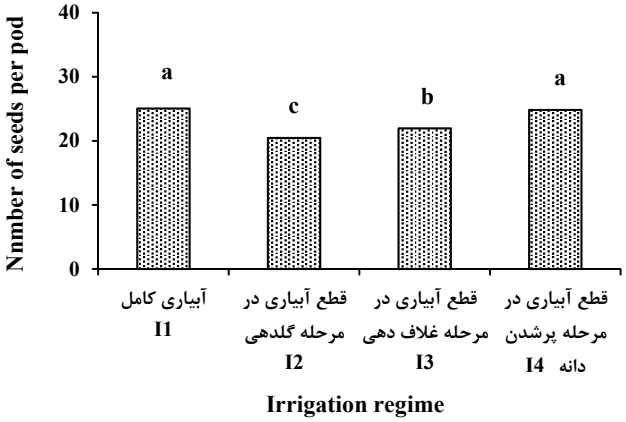

Fig. 3. The mean of number of seeds per pod of soybean under complete irrigation and drought stress condition. I_1= Complete irrigation, I_2= Water deficit at the flowering stage, I_3= Water deficit at the pod set stage, I_4= Water deficit at the seed filling period

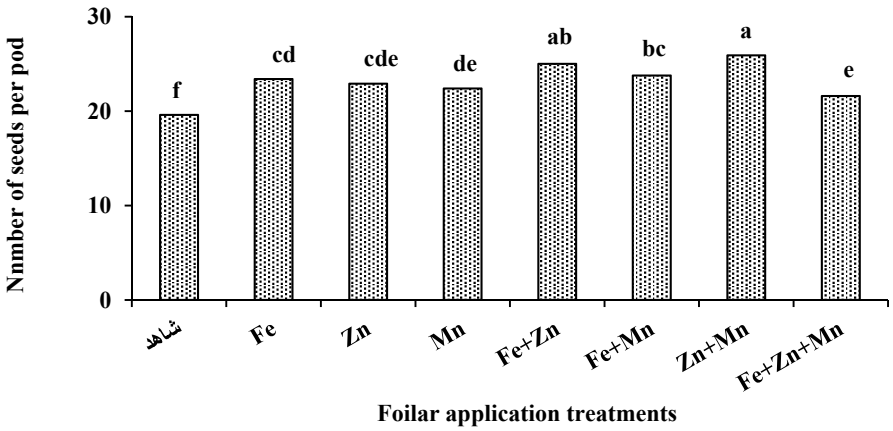

Fig. 4. Effect of foliar application of iron, zinc and manganese nano-chelate on the number of seeds per pod of soybean

Table 4. Variance analysis of soybean quantitative and qualitative traits in different irrigation treatments and Fe, Zn and Mn nano-chelate foliar application (Mean squares)

Sources of variation	df	1000-seed weight	Oil percentage	Oil yield	Protein percentage	Protein yield
Year (Y)	1	127.32^{ns}	0.64^{ns}	2416.3^{ns}	129.03^{ns}	9633.3^{ns}
Replication×Y	4	102.42	10.04	14464.2	10.37	7859.2
Irrigation (I)	3	392.31^{**}	44.31^{**}	615306.5^{**}	198.48^{**}	847613.2^{**}
Y×I	3	23.13^{ns}	0.014^{ns}	1301.8^{ns}	28.68^{ns}	12609.2^{ns}
Error	12	49.05	2.81	11934.9	5.98	6773.5
Foliar application(F)	7	975.19^{**}	36.07^{**}	203926.1^{**}	153.46^{**}	602286.1^{**}
Y×F	7	7.42^{ns}	0.004^{ns}	3355.7^{ns}	5.37^{ns}	12435.6^{ns}
I×F	21	23.52^{**}	0.54^{**}	9927.2^{**}	2.58^{*}	10204.6^{*}
Y×I×F	21	8.21^{ns}	0.02^{ns}	3419.2^{ns}	1.49^{ns}	4758.8^{ns}
Total error	112	71.32	4.29	9136.7	13.41	24277.1
C.V (%)		9.54	9.95	15.8	10.44	14.31

ns, * and **: Non-significant and significant at 5% and 1% probability levels, respectively

Table 5. Mean comparison of soybean quantitative and qualitative traits in different irrigation treatments and Fe, Zn and Mn nano-chelate foliar application

Irrigation	Foliar applicatio	1000-seed weight	Oil percentage	Oil yield	Protein percentage	Protein yield
		g	%	Kg.ha^{-1}	%	Kg.ha^{-1}
Complete irrigation	Control	113.7 ^{f}	19.15 ^{d}	496.21 ^{f}	28.84 ^{e}	747.30 ^{e}
	Fe	123.0 ^{d}	21.38 ^{c}	697.77 ^{bc}	34.07 ^{c}	1094.02 ^{c}
	Zn	119.7 ^{e}	21.37 ^{c}	687.13 ^{bc}	34.71a ^{b}	1116.10 ^{bc}
	Mn	129.0 ^{c}	22.41 ^{b}	770.03 ^{b}	34.22 ^{bc}	1175.83 ^{b}
	Fe+Zn	122.2 ^{d}	22.78 ^{b}	820.28 ^{ab}	35.28 ^{ab}	1270.39 ^{ab}
	Fe+Mn	131.6 ^{b}	23.31 ^{ab}	774.47 ^{b}	34.87 ^{b}	1158.55 ^{b}
	Zn+Mn	136.1 ^{a}	23.73 ^{a}	879.12 ^{a}	35.78 ^{a}	1325.50 ^{a}
	Fe+Zn+Mn	117.5 ^{e}	21.60 ^{bc}	603.87 ^{de}	33.62 ^{d}	939.91 ^{cd}
	Mean	*124.1*	*21.96*	*716.11*	*33.92*	*1103.45*
Water deficit at the flowering stage	Control	102.3 ^{e}	18.32 ^{e}	384.26 ^{e}	27.48 ^{e}	576.39 ^{e}
	Fe	115.8 ^{c}	21.20 ^{bc}	527.32 ^{c}	33.33 ^{c}	829.05 ^{c}
	Zn	114.1 ^{c}	20.61 ^{c}	496.21 ^{cd}	33.16 ^{c}	798.39 ^{cd}
	Mn	119.9 ^{b}	21.22 ^{bc}	543.84 ^{bc}	33.63 ^{bc}	861.90 ^{bc}
	Fe+Zn	113.0 ^{c}	22.75 ^{a}	656.51 ^{a}	32.33 ^{d}	932.97 ^{ab}
	Fe+Mn	123.6 ^{a}	21.84 ^{b}	576.24 ^{b}	33.96 ^{b}	896.03 ^{b}
	Zn+Mn	119.5 ^{b}	22.33 ^{a}	642.92 ^{a}	35.27 ^{a}	1015.56 ^{a}
	Fe+Zn+Mn	108.2 ^{d}	20.46 ^{cd}	472.15 ^{cd}	32.97 ^{cd}	760.84 ^{d}
	Mean	*114.3*	*21.09*	*469.45*	*32.76*	*833.89*
Water deficit at the pod set stage	Control	79.6 ^{c}	17.81 ^{e}	288.89 ^{f}	29.34 ^{e}	475.92 ^{e}
	Fe	94.1 ^{ab}	20.32 ^{c}	429.21 ^{cd}	36.22 ^{cd}	801.29 ^{c}
	Zn	92.8 ^{b}	20.23 ^{c}	433.26 ^{cd}	36.98 ^{c}	792.01 ^{cd}
	Mn	87.5 ^{c}	20.47 ^{c}	454.08 ^{c}	37.30 ^{bc}	827.42 ^{bc}
	Fe+Zn	97.8 ^{a}	21.64 ^{a}	565.62 ^{a}	37.77 ^{ab}	987.23 ^{a}
	Fe+Mn	94.8 ^{ab}	20.99 ^{ab}	516.33 ^{b}	37.58 ^{b}	924.43 ^{b}
	Zn+Mn	98.1 ^{a}	21.27 ^{b}	528.62 ^{ab}	38.51 ^{a}	957.08 ^{ab}
	Fe+Zn+Mn	86.6 ^{d}	20.04 ^{d}	383.70 ^{e}	35.35 ^{d}	686.84 ^{d}
	Mean	*91.4*	*20.34*	*449.96*	*36.13*	*806.53*
Water deficit at the seed filling period stage	Control	91.5 ^{e}	17.47 ^{e}	307.83 ^{e}	31.01 ^{e}	546.64 ^{d}
	Fe	100.2 ^{d}	19.83 ^{c}	395.66 ^{d}	37.98 ^{c}	757.81 ^{c}
	Zn	117.2 ^{b}	20.21 ^{b}	444.66 ^{cd}	37.77 ^{c}	831.01 ^{bc}
	Mn	108.1 ^{c}	19.84 ^{c}	478.83 ^{c}	38.36 ^{ab}	925.81 ^{b}
	Fe+Zn	115.1 ^{bc}	20.63 ^{a}	547.82 ^{a}	39.11 ^{a}	1038.64 ^{a}
	Fe+Mn	112.5 ^{bc}	20.16 ^{b}	519.38 ^{b}	38.61 ^{ab}	994.70 ^{ab}
	Zn+Mn	120.1 ^{a}	20.45 ^{a}	528.34 ^{ab}	39.57 ^{a}	1022.33 ^{a}
	Fe+Zn+Mn	99.1 ^{d}	19.64 ^{cd}	408.62 ^{d}	36.42 ^{d}	757.75 ^{c}
	Mean	*107.9*	*19.78*	*453.89*	*37.35*	*859.34*

Means followed by the same letters are not significantly different by the Duncan test 5% probability level