Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 3, No. 2, p. 39-45, 2013
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Impact of micronutrients foliar application on soybean yield and its components under water deficit condition

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Article published on February 18, 2013

Key words: Foliar application, grain yield, manganese, micronutrient, soybean.

Abstract

In order to study the effects of micronutrients foliar application on soybean yield under water deficit conditions, an experiment was conducted in a split plot based on randomized complete block design with three replications in Kermanshah province, Iran at 2010 growing season. In this research, treatments included four irrigation regimes and eight micronutrient foliar applications. At the V4 growth stage, the plats were sprayed twice (with one week interval) with 0.5% (*w/v*) or distilled water until the leaves were wet. At the end of growth season and harvesting time, the grain yield and yield components were determined. The results was showed that except for 100-seed weight per plant, other evaluated traits affected by irrigation regimes and micronutrients foliar application. Water deficit at flowering stage reduced plant height, Number of node, pod, and seed per plant, number of sub branch and grain yield by 21.5%, 24.9%, 24.9%, 33.8%, 32.0% and 29.3% compared check treatment, respectively. In the other side, spray of manganese increased grain yield by 29.6% compared M0 treatment. Indeed, Mn used was decreased the adverse effects of drought stress.

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Introduction

There were relationships between food balance and Nutritional status with growth parameters of plants. Also, Drought stress is environmental condition that cause adverse limits the growth and the production of crops. Moreover, in some plants the adverse effects of water deficit can be ameliorated by micronutrient fertilizers application. Thus, it is important to understand how drought stress may be alleviated by the supply of micronutrients. Indeed, the mechanisms that increase the resistance of plants to biotic and abiotic stress related to the micronutrients status of plants (Peleg *et al.,* 2008; El-Fouly *et al.,* 2011). Soybean production is reduced due to Fe, Mn and Zn deficiency, especially in calcareous soils where availability of these micronutrients is significantly reduced (Khudsar *et al.,* 2008, Caliskan *et al.,* 2008). Low soil moisture is an important factors that deducing solubility and mobility of micronutrients. Transport of elements from the soil to root surface occurs via diffusion and this process affected by soil moisture (Cakmak, 2008). Most of the soils of semi-arid regions, being low in soil moisture, are also low in fertility (Ashraf *et al.,* 2012). Therefore, foliar micronutrients application has been considered as an effective method to micronutrient supply at this condition. Also, foliar micronutrients applications have been reported to increase yield in wheat (Bybordi and Malakouti, 2003), sunflower (Babaeian *et al.,* 2011; Ebrahimian and Bybordi, 2011), canola (Bybordi and Mamedov, 2010), cotton (Sankarnarayanan *et al.,* 2010), corn (Abdolsalam *et al.,* 1994) and soybean (Zocchi *et al.,* 2007). In many cases, soybean yield reduction occurs without the appearance of any visible foliage symptoms. Foliar fertilization of nutrients due to the rapid translocation of these nutrients to leaf and seed is superior to soil application (Neumann, 1982). In the other side, in Western part of Iran, planting and growing of soybean coincidences with warm seasons when there is a little or no rainfall and regular irrigation is necessary (Kobraee and Shamsi, 2012a). In addition, foliar micronutrients are useful in enhancing soybean resistance to environmental stress such as water shortage (Ghasemian *et al.*, 2010). Therefore, in this research, the role of micronutrients foliar application in improving the drought tolerance potential and productivity of soybean is reviewed. In the other words, effects of drought stress and nutritional factors on yield and yield components of soybean (*Glycine max* L.) plant were assessed simultaneously.

Materials and methods

A field experiment was conducted as a split plot based on Randomized Complete Block with three replicates in 32 plots at Agricultural Research field of Islamic Azad University of Kermanshah province, Iran (34°23' N, 47°8' E; 1351 m elevation) in 2010 growing season. The main plot includes: four irrigation regimes: (I1) Irrigation at all of growth stages, (I2) Irrigation Withholding at flowering stage, (I3) Irrigation Withholding at pod set stage and (I4) Irrigation Withholding at seed filling period. There were eight foliar treatments which consisted: (1) spray with distilled water, (2) zinc spray, (3) manganese spray, (4) iron spray, (5) zinc and manganese spray, (6) zinc and iron spray, (7) manganese and iron spray, and (8) zinc, manganese and iron spray, are replaced in sub plot. Before planting, soil samples were collected from experimental area at 0-30 cm depth. The results of soil analysis were shown in Table 1.

Table 1. The results of soil test (0-30) cm.

Soil properties	value
Soil texture	Silty clay
Organic matter (%)	2.6
pH	7.3
Electrical conductivity (dsm^{-1})	0.96
N (%)	0.11
P (ppm)	8.2
K (ppm)	531
zinc (mg/kg)	0.81
Iron (mg/kg)	2.76
Manganese (mg/kg)	4.49

Table 2. Analysis of variance of soybean yield and yield components under irrigation treatments and foliar application.

Source of variation	d.f	Ms: Plant height	Number of node per plant	Number of sub branch	Number of pod per plant	Number of seed per plant	100-see weight per plant	Grain yield
Block	2	51.87	0.01	0.21	0.55	7.56	72.91	1568.09
Irrigation treatments (I)	3	1745.39**	72.82**	3.79**	452.57**	959.55**	132.28 ns	2295148.71**
Error a	6	6.47	0.50	0.10	5.51	2.46	108.67	1834.54
Foliar application (F)	7	111.28**	3.58**	0.41**	91.21**	117.39**	96.54 ns	333493.47**
(I) × (F)	21	89.34**	3.76**	0.22**	13.71**	7.21 ns	102.96 ns	20166.45*
Error b	56	16.06	0.61	0.05	5.33	6.79	103.24	9208.44
Coefficient of variation (%)	-	9.79	8.75	8.81	7.22	6.58	6.87	10.26

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

Table 3. Means comparison of soybean yield and yield components under interaction effects of irrigation regimes and micronutrients foliar application -Similar letters in each column shows non-significant difference according to LSD test in %5 level.

Treatments	Plant height (cm)	Number of node per plant	Number of sub branch	Number of pod per plant	Number of seed per plant	100-seed weight	Grain yield ($kgha^{-1}$)
M0I1	86.4cdef	17.3defg	2.9cde	40.7cde	43.8de	13.9a	1972d
ZnI1	89.4bcdef	17.7bcde	2.6efgh	39.7def	47.1bcd	14.6a	2171bc
MnI1	95.4ab	18.9ab	3.2bc	45.2ab	52.8a	14.8a	2539a
FeI1	87.3cdef	17.1defg	2.8def	38.2defghi	48.2bc	14.3a	2215bc
ZnMnI1	91.7abc	18.1abcd	3.0bcd	43.6bc	47.6bcd	14.7a	2290bc
ZnFeI1	90.2bcde	18.7abc	3.6a	39.8def	46.2cd	14.7a	2208bc
MnFeI1	97.3a	19.1a	3.3ab	48.1a	53.6a	14.5a	2482a
ZnMnFeI1	90.1bcde	17.5cdef	2.8def	43.8bc	50.8ab	14.4a	2315b
M0I2	54.9k	10.5m	1.4l	26.3k	30.5lm	14.0a	1432i
ZnI2	62.7j	12.7l	1.9k	29.9k	33.8jklm	14.6a	1627efgh
MnI2	73.2hi	14.1jk	2.1ijk	33.8j	40.2ef	14.7a	1940d
FeI2	66.0j	14.1jk	2.3hij	27.6k	31.5m	14.3a	1483i
ZnMnI2	79.6gh	15.3ij	2.3hij	34.7ij	35.1hijkl	14.5a	1674e
ZnFeI2	68.2ij	13.0kl	2.0jk	28.8k	31.5lm	14.7a	1480ghi
MnFeI2	83.2fg	16.1ghi	2.4ghi	37.8defghi	35.8ghijk	14.3a	1650ef
ZnMnFeI2	83.5g	16.2ghi	2.1ijk	35.9ghij	35.5ghijkl	14.5a	1674e
M0I3	86.2cdef	16.9defgh	2.6efgh	29.4k	35.2hijkl	14.1a	1617efgh
ZnI3	87.1cdef	17.7bcde	2.4ghi	35.6hij	39.6efg	14.5a	1866d
MnI3	91.3abcd	18.1abcd	3.3ab	38.6defgh	44.7cd	14.7a	2150c
FeI3	88.2cdef	17.0defgh	2.7defg	34.7ij	31.7klm	14.1a	1471hi
ZnMnI3	85.4cdefg	17.1defgh	2.8def	39.6defg	39.2fgh	14.6a	1861d
ZnFeI3	87.2cdef	17.1defgh	2.7defg	37.9defghi	35.0hijkl	14.5a	1675e
MnFeI3	85.3cdefg	17.1defgh	2.6efgh	36.1fghij	39.2fgh	14.7a	1897d
ZnMnFeI3	85.1defg	16.0hi	2.0jk	39.4defg	36.8fghij	14.3a	1667e
M0I4	87.1cdef	17.5cdef	2.7defg	37.6efghi	35.6ghijkl	13.2a	1610efgh
ZnI4	86.9cdef	17.0defgh	2.5fgh	37.6efghi	37.6fghij	13.1a	1632efg
MnI4	85.1defg	16.3fghi	2.5fgh	39.7def	44.5cd	13.5a	1967d
FeI4	87.0cdef	17.2defgh	2.7defg	35.3hij	34.4ijklm	13.3a	1448i
ZnMnI4	85.1defg	16.7efgh	2.5fgh	37.9defghi	37.3fghij	13.4a	1630efg
ZnFeI4	83.2fg	16.1ghi	2.5fgh	36.2fghij	35.4ghijkl	13.1a	1501fghi
MnFeI4	84.6efg	17.2defgh	2.8def	41.4cd	38.7fgh	13.1a	1670e
ZnMnFeI4	85.4cdefg	16.8efgh	2.5fgh	37.2efghij	38.2fghi	13.2a	1635efg

I1: Irrigation at all of growth stages, I2: Irrigation Withholding at flowering stage, I3: Irrigation Withholding at podset stage, I4: Irrigation Withholding at seed filling period, and M0: distilled water spray.

Soybean seeds (cv. Williams) were inoculated with *Bradyrhizobium japonicum* and sown at a high-planting rate the field. When the unifoliate leaves were expanded, the plots were hand-thinned to obtain a uniform plant population of 33 plants per m^2. The quantity of irrigation water in each plot was calculated according to Karam *et al.,* (2005), controlled by counter and exercise irrigation treatments at different growth stages according to Fehr and Caviness, (1977). At the V4 growth stage, the plats were sprayed twice (with one week interval) with 0.5% (*w/v*) or distilled water until the leaves were wet. At the end of growth season and harvesting time, the grain yield and yield components were determined. To calculate final and biological yield, $1m^2$ middle rows of each plot were completely harvested by taking margins into account. After deducting 13% moisture, grains dry weight was calculated and considered as economic yield. Also, oil and protein percent in soybean seed were measured according to Emami, (1996) and Jung *et al.,* (2003). Data for evaluated traits were statistically analyzed using a standard analysis of Variance technique for the factorial experiment in randomized complete block design using the statistical software MSTATC. Means were separated by the LSD (Least Significant Difference Test) at 5 percent probability level. Excel software was used to draw figures.

Results and Discussion

Results of variance analysis were shown that except for 100-seed weight per plant, other evaluated traits affected by irrigation regimes and micronutrients foliar application at 1% level (Table 1). Moreover, the effects of (I) × (F) interaction had significantly effects on plant height, number of node per plant, number of sub branch and number of pod per plant at 1% ($P<0.01$) and grain yield at 5% levels ($P<0.05$), while, had not significant effect on 100-seed weight per plant (Table 1). Water deficit at flowering stage had the greatest impact on the measured traits and reduced plant height, Number of node, pod, seed per plant, number of sub branch and grain yield by 21.5%, 24.9%, 24.9%, 33.8%, 32.0% and 29.3% compared check treatment (irrigation at all of growth stages), respectively (Fig 1). Irrigation withholding at flowering stage decreased grain yield from 2274.3 in check treatment to 1608.8 kg ha^{-1}. In previous study we have demonstrated that soybean grain yield reduced between 24.2 to 53.4 percent at drought stress conditions (Kobraee and Shamsi, 2012a), that these results are agreed to Ma *et al.,* (2001) and Rao *et al.,* (2002). Comparison of grain yield among irrigation withholding treatments showed that the effect of drought stress at pod set was less than irrigation withholding at flowering and seed filling period stages. The response of soybean to water deficit is related to Maturity group (Kobraee and Shamsi, 2012b; Abayomi, 2008), timing and the intensity of water stress (Korte *et al.,* 1983; Kobraee and Shamsi, 2011a). Admittedly, manganese foliar application separately, and/or combined with iron, had greater effects on evaluated traits compared zinc either separately or in combination with other elements. So that, the highest number of sub branch, seed number and grain yield were achieved with Mn foliar, and MnFe foliar application resulted in a higher plant height, number of node per plant and number of pod per plant (Fig 2). The results of this study indicated that spray of manganese increased grain yield, number of sub branch, and number of seed per plant by 29.6%, 15.3%, and 24.8% compared M0 (distilled water spray), respectively. Also, pod number per plant increased by 24.5% MnFe was used. Grain yield recorded 2149.6 kg ha^{-1} in Mn foliar compared with 1658.9 kg ha^{-1} in M0 treatment. Similar findings have also been reported in other researches (Kobraee and Shamsi, 2011b; Kobraee *et al.,* 2011; Fageria, 2009; Baybordi and Malakouti, 2003). There is a little different between Zn used and it's combined with other micronutrients concerning grain yield. The results of means comparison showed that the highest plant height, number of sub branch, number of pod and seed per plant, and grain yield were obtained in interaction effects of MnFe and irrigation at all of growth stages (Table 2). Whereas, most sub branch was observed in ZnFe foliar application and regular irrigation. In contrast, without foliar application (M0 treatment), evaluated traits were minimal, and specially withholding irrigation was occurred at flowering stage. When drought stress occurred at pod set stage manganese foliar application led to increased grain yield of 2150 kg ha^{-1} while, in M0 treatment, grain yield was recorded 1617 kg ha^{-1}. Indeed, Mn used was decreased the adverse effects of drought stress. The similar result was obtained when that irrigation withholding occurred at flowering stage. Whereas, iron foliar application had no significantly impact on grain yield. Sawada *et al.,* (2004) and Freeman *et al.,* (2005) emphasized that micronutrients fertilization increases tolerance of soybean to important biotic and abiotic stress. Finally, at these experimental terms and Based on results obtained in Table (2), micronutrient use efficiency is higher when sufficient water is available, and in drought stress conditions manganese foliar application resulted was better than the other micronutrients.

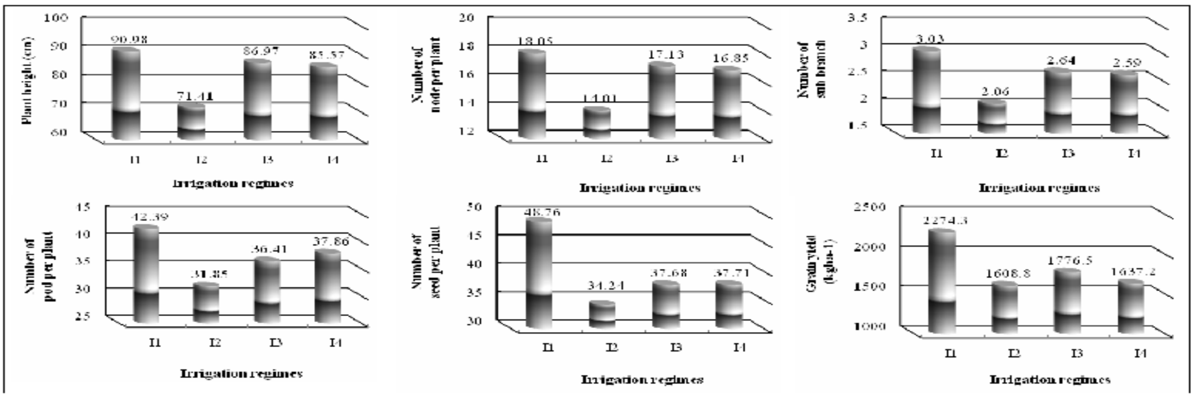

Fig. 1. The effects of irrigation regimes on evaluated traits of soyben -I1: Irrigation at all of growth stages, 12: Irrigation Withholding at flowering stage, 13 Irrigation Withholdihg at pod set stage and 14: Irrigation Withholding at seed filling period.

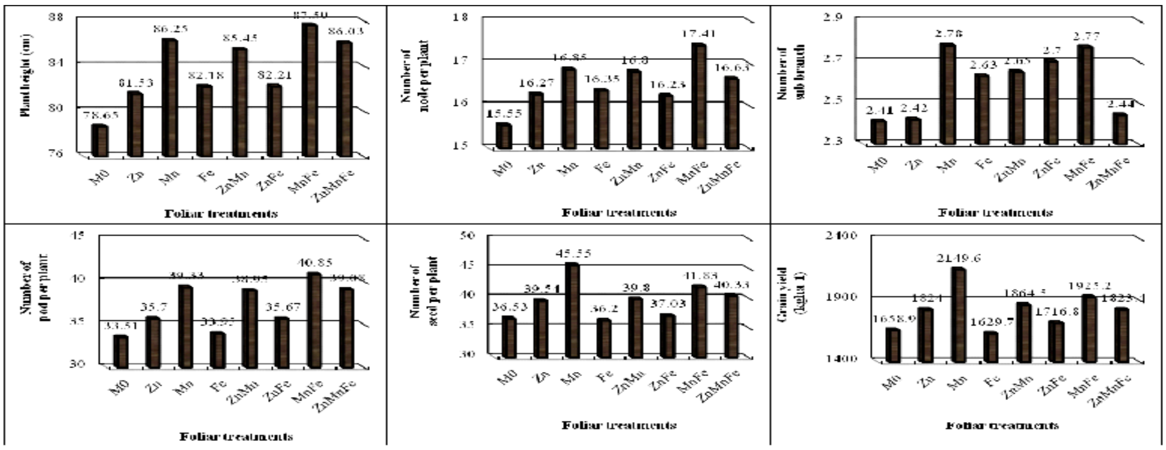

Fig. 2. The effects of Micronutrients foliar application evaluated traits of soybean –M0: distilles water.

Acknowledgments

Thanks from The Islamic Azad University for supporting projects. This research was supported by Islamic Azad University, Kermanshah Branch, Kermanshah, Iran.

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