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Influence of Short-Term Drought Stress and Manganese Treatments on Yield and Quality of Soybean Cultivars

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ABSTRACT

In order to assess responses of eight soybean cultivars to drought stress and manganese foliar application, a field experiment was conducted as split plot based on randomized complete block design with three replicates at research station of Islamic Azad University, Kermanshah province, Iran during 2012, growing season. At the end of growing season, economic and biological yield were determined. Also, oil and protein contents in soybean grain were measured. Statistical analysis showed that irrigation and manganese interaction had significant effects on economic and biological yield, while, this treatment had no significant effects on oil and protein in soybean grain. In addition, there are significant differences among cultivars in economic and biological yield. Based on results obtained, withholding irrigation at flowering stage reduced oil, protein, economic and biological yield, but this reduction was not statistically significant for the oil. The lowest oil, protein, economic and biological yield were recorded in $I_2Mn_0C_2$, $I_1Mn_0C_4$, $I_2Mn_0C_5$ and $I_2Mn_0C_4$ treatments. There was a significant and positive correlation between economic yield with oil percentage and biological yield.

Key words: Micronutrient, oil, protein, soybean, yield

INTRODUCTION

Availability of micronutrients in calcareous soil is influenced by soil moisture. Also, in calcareous soils wet and dry periods can influence manganese availability by root plants. Under drought stress, plant roots cannot absorb micronutrients (Heidarian *et al*., 2011), such as manganese and foliar spraying of manganese is useful and more influential as compared to soil application (Narimani *et al*., 2010). In the other side, Soybean is considered a sensitive crop to drought stress (Lobato *et al*., 2008) and manganese deficiency (Barker and Pilbeam, 2007). Manganese fertilization could be very important in the case of soybean grown in soil with low manganese availability (Hellal and Abdelhamid, 2013), especially at water deficit conditions (Vadez *et al*., 2000). Recent evidence in the literature indicates that deficiencies in minerals due to drought stress at any plant growth stage result in poor seed quality and low yield (Bellaloui *et al*., 2013). In addition, drought stress is recognized as a affecting factor in soybean oil and protein contents (Kumawat *et al*., 2000; Rotundo *et al*., 2009; Kirnak *et al*., 2010). Based on Wilson (1995), Liu *et al*. (1995) and Maestri *et al*. (1998) studies protein and oil content, chemical composition of oil and protein and grain appearance are three important factors determining the quality of soybean. Previous studies indicated that there exists an inverse relationship between seed protein and oil concentration (Panthee *et al*., 2006; Okporie and Oselebe, 2007) and there is

positively correlation between quality traits with seed yield as a quantity trait (Rajni *et al*., 1983). Therefore, the main objective of this study was to evaluate the effects of withholding irrigation and manganese foliar treatments on some quantitative and qualitative traits in eight cultivars of soybean.

MATERIALS AND METHODS

This experiment was conducted as split split plot in randomized complete block design with three replications in 96 plots at Agricultural Research field of Islamic Azad University of Kermanshah, Iran (34˚23'N, 47˚8'E; 1351 m elevation) during 2012 growing season. Eight commercial soybean cultivars, Clark (V_1), Williams (V_2), Sahar or Pershing (V_3), Hobbit (V_4), Gorgan 3 (V_5), M7 (V_6), M9 (V_7) and DPX (V_8), were grown under field conditions. Main plot treatments consisted two irrigation regimes: (I_1) Irrigation at all of growth stages, (I_2) Irrigation Withholding at flowering stage, Subplot included (Mn_0) spray with distilled water, (Mn_1) manganese spray and eight soybean cultivars arraigned in sub subplot. Soil samples were collected from experimental area at 0-30 cm depth. The texture of the soil based on silty clay with (silt 49.1%, clay 42.4% and sand 8.5%), pH 7.3, organic matter 2.6, total nitrogen 0.11%, available phosphorus, potassium, zinc, iron and manganese 8.2, 531, 0.81, 2.76 and 4.49, respectively. All seeds were inoculation with *Bradyrhizobium japonicum* immediately before sowing. Each plot was 6 m in length, 2.4 m in width, 0.6 m in row spacing and with density of 33 plants per meter square. The quantity of irrigation water in each plot was calculated according to Karam *et al*. (2005), controlled by counter and exercise irrigation treatment at flowering stage. At the V_4 growth stage based on Fehr and Caviness (1977), the plants were sprayed twice (with one week interval) with 0.5% manganese liquid or distilled water until the leaves were wet. At the end of growing season and harvest time, two middle rows of each plot were completely harvested considering the sides. Weight 13% deduction of moisture, grain dry weight was calculated and considered as economic yield. To determine biological yield, total plant dry weight was employed as biological yield. Also, oil and protein contents in soybean grain 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 using the MSTATC software. Means were separated by the Least Significance Difference Test (LSD) at 5 percent probability level.

RESULTS AND DISCUSSION

The results of analysis of variance were shown in Table 1. Irrigation treatments made significant effects on oil at 5% level and economic and biological yield at 1% level. The similar results were reported by Aderolu (2000). Also, manganese foliar application had significant effects on protein ($p<0.05$) and economic and biological yield ($p<0.01$). While, Protein and oil unaffected by irrigation and manganese treatments, respectively (Table 1). The positive effect of manganese foliar application on seed protein of safflower was emphasized by Movahhedy-Dehnavy *et al*. (2009). Statistical analysis showed that irrigation and manganese interaction had significant effects on economic and biological yield, while, (I) × (Mn) treatment had no significant effects on oil and protein in soybean grain. The similar results were obtained by Babaeian *et al*. (2011). The results of this experiment show that there are significant differences among cultivars in economic and biological yield ($p<0.01$). Among soybean cultivars there was no significant difference in terms of oil and protein. Effect of (I) × (C) and (Mn) × (C) interactions on biological yield were significant probability levels at 1 and 5%, respectively. Whereas, other evaluated traits unaffected by these

Table 1: The results of analysis variance of oil, protein, economic and biological yield in eight soybean cultivars under short-term drought stress and manganese foliar application

		MS			
Source of variation	df	Oil	Protein	Economic yield	Biological yield
Replication	2	8.46	2.21	8298.76	8192.01
Irrigation(I)	1	57.35*	2.34^{ns}	22512782.51**	150695805.04**
Error(a)	2	1.97	6.49	26159.19	1860.51
Manganese (Mn)	1	12.04^{ns}	102.09*	1460513.34**	12009105.37**
(I)×(Mn)	1	0.51^{ns}	1.65^{ns}	95319.01**	611523.37**
Error(b)	4	1.60	10.59	10297.89	23523.53
Cultivar(C)	7	0.27^{ns}	1.18^{ns}	518187.20**	2868205.45**
(I) ×(C)	7	0.14^{ns}	0.91^{ns}	32207.27 ^{ns}	422829.59**
(Mn) ×(C)	7	0.10^{ns}	1.11^{ns}	30757.72 ^{ns}	116439.54*
(I) ×(Mn) ×(C)	7	0.37^{ns}	0.74^{ns}	41634.06*	428722.11**
Error(c)	56	0.43	2.14	17476.46	45990.79
Coefficient of variation (%)	-	6.47	8.79	9.52	10.69

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

Table 2: Means comparison of qualitative and quantitative traits in eight soybean cultivars under short-term drought stress and manganese foliar application

	Means			
Treatment	Oil (%)	Protein (%)	Economic yield (kg ha^{-1})	Biological yield (kg ha^{-1})
Irrigation				
I_1	19.64^{a}	38.51^{a}	2512.75^{a}	6674.75^{a}
I_2	18.09^{b}	38.82^{a}	1544.23^{b}	4168.96^{b}
Manganese				
Mn_0	18.52^{ab}	37.64^{b}	1905.15^{b}	5068.17^{b}
Mn_1	19.23^{a}	39.70^{a}	2151.83^{a}	5775.54^{a}
Cultivar				
C_1	18.95^{a}	38.50^{a}	2034.08^{cd}	5457.50^{c}
C_2	18.65^{a}	38.65^{a}	2305.83^{a}	6159.25^{a}
C_3	19.07^{a}	39.00^{a}	2186.08^{b}	5727.50^{b}
C_4	18.75^{a}	38.60^{a}	1931.50^{de}	5083.92^{d}
C_5	18.73^{a}	38.18^{a}	1627.50^{f}	4679.17^{e}
C_6	18.90^{a}	38.43^{a}	1826.08^{e}	4927.50^{d}
C_7	18.89^{a}	39.10^{a}	2148.25^{b}	5696.00^{b}
C_8	19.03^{a}	38.90^{a}	2123.58^{bc}	5644.00^{b}
LSD value	0.53	1.19	108.10	175.41

*Similar letters in each column shows non-significant difference according to LSD test in 5% level, **I_1: Irrigation at all of growth stages and I_2: Withholding irrigation at flowering growth stage; Mn_0: Spray with distilled water and Mn_1: Manganese spray, C_1: Clark, C_2: Williams, C_3: Pershing, C_4: Hobbit, C_5: Gorgan3, C_6: M7, C_7: M9, C_8: DPX

interaction effects. Oil and protein contents were not affected by the interaction of (I) × (Mn) ×(C). In contrast, interaction effect of (I) × (Mn) ×(C) treatment had significant effects on economic yield ($p<0.05$) and biological yield ($p<0.01$). The results of means comparison (Table 2) were shown that withholding irrigation at flowering stage in I_2 treatment reduced oil, protein, economic and biological yield compared regular irrigation (I_1 treatment), However, this reduction was not statistically significant for the oil. These results are somewhat different from the results obtained by Zaman and Das (1991). With manganese foliar application, protein content, economic and biological yield increased by 5.47, 12.95 and 13.96, respectively. Hellal and Abdelhamid (2013) reported that total manganese uptake by the soybean plants per metric ton of grain production is 123 g. Manganese fertilization increased oil content in soybean grain, but this increased was not statistically significant. These results are in contrast with the results obtained by Yasari and Vahedi (2012) that showed the highest seed oil yield in soybean was obtained by applying manganese. Economic yield ranged between 2305.83-1627.50 kg ha^{-1} in cultivars. The highest and

lowest economic yield was observed in C_2 and C_4 cultivars, respectively. The similar results for biological yield was observed and among cultivars C_2 and C_4 had the highest and lowest biological yield with 6159.25 and 4679.17 kg ha^{-1} (Table 2). Based on results obtained, the highest oil, economic and biological yield were achieved with manganese spray at regular irrigation (I_1Mn_1 treatment) by 19.92, 2605.12 and 6949.72 kg ha^{-1}, respectively. So that, there are significantly differences between cultivars concerning oil and protein contents in soybean grain at different irrigation regimes (Table 3). Furthermore, at all of cultivars evaluated the highest economic and biological yield belonged to I1 (regular irrigation). Among cultivars C_2 had the highest economic yield (2828.41 kg ha^{-1}) and biological yield (7608.43 kg ha^{-1}). Manganese application compared distilled water spray at water deficit condition led to increase in oil, protein, economic and

Table 3: The effect of (I) × (Mn) and (I) × (C) interactions on soybean qualitative and quantitative traits

	Means			
Treatment	Oil (%)	Protein (%)	Economic yield (kg ha^{-1})	Biological yield (kg ha^{-1})
(I) × (Mn)				
I_1Mn_0	19.36^{ab}	37.61^{a}	2421.26^{b}	6401.28^{b}
I_1Mn_1	19.92^{a}	39.41^{a}	2605.12^{a}	6949.72^{a}
I_2Mn_0	17.67^{c}	37.66^{a}	1389.51^{d}	3735.69^{d}
I_2Mn_1	18.52^{bc}	39.99^{a}	1699.36^{c}	4602.01^{c}
LSD value	1.013	2.609	81.331	122.910
(I) × (C)				
I_1C_1	19.70^{a}	35.25^{a}	2442.85^{c}	6484.55^{d}
I_1C_2	19.45^{a}	38.20^{a}	2828.41^{a}	7608.43^{a}
I_1C_3	19.80^{a}	38.95^{a}	2672.38^{b}	6938.06^{c}
I_1C_4	19.60^{a}	38.00^{a}	2403.74^{cd}	6283.85^{de}
I_1C_5	19.55^{a}	38.20^{a}	2141.29^{e}	5750.64^{f}
I_1C_6	19.85^{a}	38.70^{a}	2270.23^{de}	6078.65^{e}
I_1C_7	19.51^{a}	38.95^{a}	2642.68^{b}	7048.22^{bc}
I_1C_8	19.70^{a}	38.85^{a}	2705.55^{ab}	7211.52^{b}
I_2C_1	18.20^{b}	38.75^{a}	1626.34^{gh}	4431.11^{h}
I_2C_2	17.85^{b}	39.10^{a}	1784.46^{f}	4711.26^{g}
I_2C_3	18.35^{b}	39.05^{a}	1700.26^{fg}	4518.92^{gh}
I_2C_4	17.90^{b}	39.20^{a}	1460.62^{ij}	3885.71^{ij}
I_2C_5	17.90^{b}	38.15^{a}	1204.23^{k}	3609.44^{k}
I_2C_6	17.95^{b}	38.15^{a}	1383.98^{j}	3778.31^{jk}
I_2C_7	18.25^{b}	39.25^{a}	1655.71^{fgh}	4345.77^{h}
I_2C_8	18.35^{b}	38.95^{a}	1543.06^{hi}	4077.43^{i}
LSD value	0.75	1.69	152.95	248.01
(Mn) × (C)				
Mn_0C_1	18.45^{cd}	37.30^{f}	1963.51^{ef}	5238.50^{de}
Mn_0C_2	15.25^{d}	37.95^{c-f}	2136.40^{cd}	5668.36^{c}
Mn_0C_3	18.75^{a-d}	38.20^{b-f}	1991.35^{def}	5322.97^{d}
Mn_0C_4	18.55^{Bcd}	37.05^{f}	1890.42^{fg}	4853.71^{fg}
Mn_0C_5	18.40^{cd}	37.35^{ef}	1549.35^{i}	4302.19^{h}
Mn_0C_6	18.51^{cd}	37.65^{def}	1723.91^{h}	4641.60^{g}
Mn_0C_7	18.48^{cd}	38.00^{c-f}	2017.20^{def}	5256.43^{de}
Mn_0C_8	18.75^{a-d}	37.60^{def}	1974.68^{ef}	5267.66^{de}
Mn_1C_1	19.46^{a}	39.70^{ab}	2106.25^{de}	5677.82^{c}
Mn_1C_2	19.05^{abc}	39.35^{abc}	2476.09^{a}	6651.85^{a}
Mn_1C_3	19.42^{a}	39.80^{ab}	2382.13^{ab}	6134.48^{b}
Mn_1C_4	18.95^{a-d}	40.15^{a}	1973.62^{ef}	5315.76^{d}
Mn_1C_5	19.05^{abc}	39.00^{a-e}	1797.53^{gh}	5057.94^{ef}
Mn_1C_6	19.30^{ab}	39.20^{a-d}	1929.40^{fg}	5215.18^{de}
Mn_1C_7	19.30^{ab}	40.20^{a}	2280.08^{bc}	6137.25^{b}
Mn_1C_8	19.30^{ab}	40.20^{a}	2273.22^{bc}	6021.74^{b}
LSD value	0.75	1.69	152.93	248.06

[*] Similar letters in each column shows non-significant difference according to LSD test in 5% level, [**] I_1: Irrigation at all of growth stages and I_2: Withholding irrigation at flowering growth stage; Mn_0: Spray with distilled water and Mn_1: Manganese spray; C_1: Clark, C_2: Williams, C_3: Pershing, C_4: Hobbit, C_5: Gorgan3, C_6: M7, C_7: M9, C_8: DPX

biological yield by 4.81, 6.19, 22.23 and 23.19%, respectively (Table 3). These results are agreement with Movahhedy-Dehnavy *et al*. (2009) and Maghsud *et al*. (2014) findings. Fageria (2007) and Hellal and Abdelhamid (2013) emphasized that micronutrients such as manganese have important role in growth and yield of crops. In addition, Mn plays an important role in stabilization of structural protein (Popelkova *et al*., 2003). Concerning oil content in grain, response of Clark and Pershing cultivars to manganese application was better than the other cultivars tested. While, at manganese spray condition Hobbit, M9 and DPX cultivars had more protein in grains. In M_1 treatment, the highest economic and biological yield was recorded in Williams cultivar (Table 3). Means comparison of quantity and quality traits in soybean grain under (I) × (Mn) ×(C) interaction effects was shown in Table 4. Generally, the highest oil, economic and biological yield were observed when that manganese was applied in irrigation regular treatment. Bellaloui *et al*. (2013) reported that nutrients deficiencies due to drought stress at any plant growth stage result in low quality and yield of crops. While, withholding irrigation and manganese application increased protein content in soybean grain. The role of micronutrients application in protein synthesis in crops grain was emphasized by Ziaeian and Malakoti (2002) study. Clark cultivar had the highest

Table 4: Means comparison of soybean qualitative and quantitative traits under (I) × (Mn) ×(C) interaction effect

	Means			
Treatment	Oil (%)	Protein (%)	Economic yield (kg ha^{-1})	Biological yield (kg ha^{-1})
(I) ×(Mn) ×(C)				
$I_1Mn_0C_1$	19.32^{a-g}	37.12^{hi}	2353.86^{fgh}	6185.68^{f}
$I_1 Mn_0C_2$	19.11^{b-h}	37.58^{e-i}	2679.44^{bcd}	7091.84^{bcd}
$I_1 Mn_0C_3$	19.70^{a-e}	38.42^{b-i}	2509.68^{d-g}	6766.22^{de}
$I_1 Mn_0C_4$	19.52^{a-f}	36.20^{i}	2495.87^{d-g}	6389.76^{f}
$I_1 Mn_0C_5$	18.93^{c-i}	37.56^{e-i}	1976.35^{ij}	5264.00^{h}
$I_1 Mn_0C_6$	19.76^{a-e}	37.95^{d-i}	2157.71^{hi}	5651.51^{g}
$I_1 Mn_0C_7$	19.20^{a-h}	38.24^{c-i}	2609.68^{cd}	6874.21^{cd}
$I_1 Mn_0C_8$	19.51^{a-f}	38.18^{d-i}	2589.08^{de}	6987.29^{cd}
$I_1Mn_1C_1$	20.13^{ab}	39.41^{a-h}	2531.66^{def}	6783.44^{de}
$I_1 Mn_1C_2$	19.80^{a-d}	38.90^{a-h}	2976.97^{a}	8125.07^{a}
$I_1 Mn_1C_3$	19.94^{abc}	39.51^{a-g}	2835.14^{ab}	7109.73^{bcd}
$I_1 Mn_1C_4$	19.78^{a-e}	39.82^{a-e}	2311.75^{gh}	6177.70^{f}
$I_1 Mn_1C_5$	20.21^{a}	38.90^{a-h}	2306.68^{gh}	6235.41^{f}
$I_1 Mn_1C_6$	20.00^{ab}	39.55^{a-g}	2382.47^{efg}	6504.08^{ef}
$I_1 Mn_1C_7$	19.83^{a-d}	39.76^{a-f}	2675.55^{bcd}	7221.39^{bc}
$I_1 Mn_1C_8$	19.92^{abc}	39.62^{a-f}	2820.76^{abc}	7435.79^{b}
$I_2Mn_0C_1$	17.65^{kl}	37.53^{e-i}	1572.45^{m-p}	4291.55^{ij}
$I_2Mn_0C_2$	17.44^{l}	38.40^{b-i}	1592.54^{mno}	4245.76^{jk}
$I_2Mn_0C_3$	17.80^{jkl}	38.00^{d-i}	1472.08^{n-q}	3877.12^{lm}
$I_2Mn_0C_4$	17.68^{kl}	37.96^{d-i}	1285.00^{qr}	3318.40^{n}
$I_2Mn_0C_5$	17.93^{i-l}	37.21^{ghi}	1121.47^{r}	3339.31^{n}
$I_2Mn_0C_6$	17.34^{l}	37.45^{f-i}	1289.77^{qr}	3630.71^{lmn}
$I_2Mn_0C_7$	17.77^{jkl}	37.83^{d-i}	1425.78^{opq}	3637.90^{lmn}
$I_2Mn_0C_8$	18.04^{i-l}	37.09^{hi}	1359.06^{pq}	3547.64^{mn}
$I_2Mn_1C_1$	18.81^{d-j}	40.08^{a-d}	1680.91^{lmn}	4571.27^{ij}
$I_2Mn_1C_2$	18.33^{g-l}	39.81^{a-e}	1976.05^{ij}	5176.06^{h}
$I_2Mn_1C_3$	18.90^{c-i}	40.11^{a-d}	1928.28^{jk}	5158.98^{h}
$I_2Mn_1C_4$	18.22^{h-l}	40.50^{abc}	1635.62^{mno}	4452.01^{ij}
$I_2Mn_1C_5$	17.90^{i-l}	39.10^{a-h}	1287.12^{qr}	3879.80^{lm}
$I_2Mn_1C_6$	18.63^{f-k}	38.94^{a-h}	1476.33^{n-q}	3925.27^{kl}
$I_2Mn_1C_7$	18.85^{d-j}	40.70^{ab}	1884.43^{jkl}	5052.54^{h}
$I_2Mn_1C_8$	18.72^{e-j}	40.89^{a}	1726.51^{klm}	4607.25^{i}
LSD value	1.07	2.39	216.21	350.80

* Similar letters in each column shows non-significant difference according to LSD test in 5% level, **I_1: Irrigation at all of growth stages and I_2: Withholding irrigation at flowering growth stage; Mn_0: Spray with distilled water and Mn_1: Manganese spray; C_1: Clark, C_2: Williams, C_3: Pershing, C_4: Hobbit, C_5: Gorgan3, C_6: M7, C_7: M9, C_8: DPX

Table 5: Pearson correlation coefficients among evaluated traits in eight soybean cultivar under short-term drought stress and manganese application

	O (%)	P (%)	Economic yield	Biological yield
O%	1.00	0.077^{ns}	0.692^{*}	0.680^{*}
P%		1.00	0.090^{ns}	0.099^{ns}
Economic yield			1.00	0.965^{**}
Biological yield				1.00

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

oil content in the grains. Among cultivars, DPX had more protein in the grain and the highest economic and biological yield belonged to Williams cultivar. The lowest oil, protein, economic and biological yield were recorded in $I_2Mn_0C_2$, $I_1Mn_0C_4$, $I_2Mn_0C_5$ and $I_2Mn_0C_4$ treatments. There was a significant and positive correlation between economic yield with oil percentage ($r = 0.692^{*}$) and biological yield ($r = 0.965^{**}$) (Table 5). Also, biological yield had a significant and positive correlation with oil content in soybean grain ($r = 0.680^{*}$). In our experimental conditions, a significant correlation between oil and protein content in soybean grain was not recorded.

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