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Effects of Nutrients Foliar Application on Agrophysiological Characteristics of Maize under Water Deficit Stress

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Abstract

To investigate effects of nutrients foliar application on agrophysiological characteristics of maize hybrid 'KSC 704' water deficit stress conditions, an experiment was arranged in a split plot factorial based on a randomized complete block design with four replications to the Research Station of Islamic Azad University-Arak Branch, Iran in 2007-2008. Main factors studied were four irrigation levels including irrigation equal to crop water requirement, water deficit stress at eight-leaf stage (V8), blister stage (R2) and filling grain stage (R4) in the main plot. Combined levels of selenium treatment (without and with application 20 gha^{-1}) and micronutrients (without and with application 2 lha^{-1}) were situated in sub plots. Results showed that water deficit stress decreased grain yield 19.7% in blister stage as compared with control. Using selenium increased relative content water at R2 and R4 stages significantly. Using selenium in water deficit stress condition increased measured traits except plant height as compared with treatment without selenium. A negative antagonistic interaction was found between selenium and micronutrients on some measured traits. Between treatments of water deficit stress, highest grain yield equal 6799.52 and 6736.97 $kgha^{-1}$ was obtained from combined treatments of water deficit stress at eight-leaf stage+without selenium+without micronutrients and water deficit stress at eight-leaf stage+selenium+without micronutrients respectively which compared with treatment of irrigation equal to crop water requirement+selenium+microelements did not differ significant. According to the results of experiment, it is concluded that with micronutrients fertilizer spray under optimum irrigation and selenium spray under water deficit obtain optimum yield.

Keywords: water deficit stress, selenium, relative content water, grain yield

Introduction

In many regions of the world, including Iran, drought stress is one of the most important factors that decrease agricultural crop production. Efficient water management will enhance the food supply in the coming decades (Yudelman, 1994). Proper management of inputs using modern technology, particularly irrigation water management and nutrient application is essential to maximize crop production and returns for the farmers (Panda *et al*., 2004). Water shortage during the vegetative stages of development limits the grain yield in many maize production areas. Pandey *et al*. (2000) reported that yield reduction (22.6-26.4%) caused by deficit irrigation was associated with a decrease in kernel number and weight. Karam *et al*. (2003) stated that grain yield was reduced by 37% due to a decline of 18% in kernel weight and 10% in kernel number under water stress conditions.

Heavy metals, such as Fe, Cu, Mn and Zn, function as micronutrients and are indispensable for plant growth (Haydon and Cobbett, 2007). Deficiencies of these heavy metals cause severe growth reduction (Broadley *et al.,* 2007; Marschner, 1995). Several metabolic processes, such as photosynthesis, cellular respiration, nutrient uptake and photolysis of water, may be affected by the presence of microelements like Zn, Cu, Fe, Mn and Mo (Sikora and Cieslik, 1999). Soils of Iran are deficient in organic matter. Similarly, most of micronutrients, for example Fe and Mn are readily fixed in soil having alkaline pH. Plant roots are unable to absorb these nutrients adequately from dry topsoil (Foth and Ellis, 1996; Graham *et al*., 1992). Foliar spray of different micronutrients has been reported to be equally or more effective as soil application by different researchers (Torun *et al.,* 2001).

Selenium is an essential micronutrient for animals, but its nutritional requirement in plants is not clearly understood. Selenium enrichment of crop plants results in the transformation of inorganic Se to bioavailability organic Se compounds within the plants (Gissel-Nielsen, 1994). In some plant species drought stimulates oxidation process which causes accumulation of poisonous oxygen such as free oxygen radical, hydrogen peroxide and hydroxyl radicals. Oxidative stress can prevent photosynthetic activity, respiration process and plant growth. Plants are naturally provided by enzymatic and non-enzymatic systems to take care active oxygen (Giang and Huang, 2001). Selenium may increase the tolerance of plant to UV-radiation induced oxidative stress, delay senescence and promote the

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growth of ageing seedling (Djanaguiraman *et al*., 2005). Result from Pennanen *et al.* (2002) has showed that plant growth promoted by selenium is due to increased starch accumulation in chloroplast. Recently, it has been shown that selenium can regulate the water status of plant under condition of water deficiency and thereby has a protective effect (Kuznetsov *et al*., 2003). The goal of this work was to determine the response on some agro physiological characteristics of maize to the combined effects water deficit, microelements and selenium foliar application.

Materials and methods

This experiment was conducted at Agricultural Research Station of Islamic Azad University, Arak Branch with 1779 m above sea level in Markazi province in center Iran in 2007 and 2008. The experimental design was split plot factorial based on randomized complete block design with four replications. Four irrigation levels including, without water stress (control), water deficit stress in Vegetative stage (V8), water deficit stress in blister stage (R2) and water deficit stress in grain filling stage (R4) were assigned to main plot. Water stress was executed by temporary stopping irrigation at each mentioned stages. In control treatment, irrigation conducted in equal crop water requirement. Crop water requirement was calculated by evaporation basin. Daily evaporation was measured from basin. Basin coefficient and crop coefficient was determined, amount of water consumed for each crop growth stage. Amount of water to plots was controlled by water contour. Irrigation of again in stress treatments were done when soil moisture arrived at 15% weight of soil. Microelements at two levels, without and with using that was provided by specific fertilizer for maize called " biomin " which contains microelements of Fe, Zn, Cu, Mn, B, Mo and Mg in the form of foliar application at six-leaf stage and one week before tassling stage at the rate of 2 lha^{-1}. Selenium as sodium selenite ($NaHSeO_3$) at two levels (with and without) was applied two weeks before execution of water stress treatment at the rate of 20 gha^{-1}. Microelements and selenium were situated in sub plots as randomized. Soil preparation including plow was done in fall and perpendicular disks each two years. Each plot constituted seeded liners distanced 65 cm from each other and 20 cm distance between each two plants on the lines. The length of each seeded line was six meters and two furrows between each two plots were unseeded. Maize seeds (hybrid single cross 704) were hand-seeded on 18th of May each two years. A mixed sample of soil 0-30 cm deep was prepared to determine the EC of the saturated paste (Allison and Moodie, 1965) pH, texture with hydrometer (Bouyoucos, 1962), organic C percentage (Walkey and Black, 1934), total N (Kjeldahl method), the concentration of available P (Olsen *et al*., 1954) and available K with flame (U.S. Salinity Laboratory, 1954). Iron, Zn, Mn and Cu were determined with method of diethylenetriamine-pentaacetic acid (DTPA) (Lindsay and Norvell, 1979). All treatments received 187.5 $kgha^{-1}$ N as urea, 150 $kgha^{-1}$ P_2O_5 as super phosphate triple and 150 K_2O as sulphate potasium in each year. One third of N and total rate of P_2O_5 and K_2O were applied before planting. The remaining N was applied in equal rate at six-leaf stage and two week before tassling stage.

Relative water content was calculated to examine plant reaction to water deficit stress. For this purpose, leaves of three plants from second and fifth rows were separated before irrigation at 12pm and were taken to the laboratory. In the laboratory disks of the leaves were prepared and weighed immediately to measure the fresh leaf weight. Then the disks were placed in distilled water for about 24 hours at 4°C until they were saturated completely. At the end of this stage, the leaf disks were dried by towels of dry paper and were then weighed again. The samples were placed in the oven for about 48 hours at 72°C until they were dried. The weight of dried leaves was recorded. Relative water content was calculated using the following relation (Dhopte and Manuel, 2002)

$$RWC = \frac{Wf - Wd}{Ws - Wd} \times 100$$

RWC=Relative Water Content
Wf=Fresh Leaf Weight
Wd=Dry Leaf Weight
Ws=Saturated Leaf Weight

Final harvest was performed at physiological maturity stage when a black layer was formed at seed base. At maturity stage, grain yield was determined from a harvest area of 1.5×4 m (2 rows middle of each experimental plot) and expressed on a 15% moisture basis.

To determine water use efficiency the following relation was applied:

Water use economic efficiency = Grain yield ($kgha^{-1}$)/ water used (m^3 ha^{-1})

Analysis of variance was performed using PROC ANOVA of SAS. The comparison of the means was done by Duncan's test at a probability level of 5 percent.

Results and discussions

Effects of water deficit stress on Plant height, grain yield, relative content water at V8, R2 and R4 stages was significant at 1% level (Tab. 2). Mean comparison of treatments indicate that highest rate of grain yield, relative content Water at V8, R2 and R4 stages related to treatment of without water deficit stress and highest rate of water use efficiency obtained from treatment of water deficit stress in V8 stage (Tab. 3). Water deficit stress decreased Plant height 14.4% in stage V8 as compared with control. It is known that a decrease in plant height is due to a decrease in cell division and assimilate transport. There are many reports of a decrease of vegetative growth and plant height under conditions of drought stress. An increase in plant

Tab. 1. Result of physical and chemical soil analysis

Year	Depth (cm)	EC ds m-1	PH	OC%	N%	P (ppm)	K (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Se (ppm)	Sand %	Silt %	Clay %
2007	0-30	1.20	7.5	0.82	0.08	5	150	0.8	4.6	10.6	1.14	027	29	35	36
2008	0-30	1.70	7.7	0.78	0.06	8.5	130	9.2	3.9	9.2	1.1	0.23	26	38	36

Tab. 2. Combined analysis of variance for traits of maize in water deficit stress, selenium and microelements (2008-2009)

		MS					
S.O.V	df	Plant height	RWC_{V8}	RWC_{R2}	RWC_{R4}	WUE	Grain yield
Year(Y)	1	9154.52**	2368.87**	17.70 ns	630.25**	0.483*	14083664.10*
Replication (Year)	6	438.87	138.60	28.61	31.05	0.089	2679445.25
Irrigation(I)	3	4395.80**	1615.42**	265.97**	596.86**	0.067ns	8391972.81**
Y × I	3	793.82 ns	148.59 *	220.53**	663.21**	0.114*	11730544.18**
Error	18	315.67	80.41	21.01	68.47	0.027	115388.32
Selenium(Se)	1	123.59 ns	0.327ns	229.22**	266.77**	0.005ns	114990.06ns
Se× Y	1	146.59ns	29.27 ns	90.23ns	13.05ns	0.011ns	214411.12ns
Se× I	3	42.55 ns	166.02 *	100.12*	58.87ns	0.093**	6653116.13**
Se × I× Y	3	202.66 ns	213.25**	18.43*	93.32*	0.109**	6920361.48**
Microelement (M)	1	776.67ns	73.40	266.48**	42.67ns	0.062ns	3628562.64*
M× Y	1	177.09ns	0.654 ns	0.404ns	5.37ns	0.001ns	17021.52 ns
I× M	3	286.68*	39.62ns	23.38ns	171.08**	0.048*	3250076.38**
Y × I ×M	3	338.53*	57.08 ns	41.54ns	122.19**	0.006ns	438666.77 ns
Se×M	1	809.32**	191.17*	2.16ns	8.02ns	0.011ns	742736.48ns
Se× M× Y	1	179.31ns	1.38ns	90/100 ns	53.88ns	0.114 **	6558182.18**
Se× M × I	3	76.31 ns	139.92*	**05/230	136.36**	0.013ns	691369.35**
Se× M × I × Y	6	198.86ns	77.98 ns	11.33ns	**145.57	0.064*	3361080.25**
Error	72	94.94	41.88	26.94	25.55	0.016	710068.41
C.V (%)		7.12	9.29	6.51	6.72	15.23	13.06

Tab. 3. Mean comparisons plant characteristics of maize in main effects of year, irrigation, selenium and interaction of selenium × irrigation

Treatments	Plant height (cm)	RWC_{V8} (%)	RWC_{R2} (%)	RWC_{R4} (%)	WUE ($kg.m^{-3}$)	Grain yield ($kg. ha^{-1}$)
			Years			
2007	145.35a	73.93 a	79.37 a	77.01 a	0.89a	6781.55a
2008	128.41b	65.33b	80.12 a	77.45 b	0.75b	6118.14b
			Irrigation			
I0	139.63 a	74.11a	82.67 a	77.90 a	0.84ab	7076.55a
I1	119.59 b	59.06b	80.28 a	77.70 a	0.87a	6603.75ab
I2	144.15a	73.45 a	75.60 b	76.50a	0.75b	5702.05c
I3	144.14a	71.89a	80.42 a	68.82b	0.77b	5878.14bc
			Selenium			
Se0	137.86 a	69.58a	78.41 b	73.79b	0.83a	6419.87a
Se1	135.90a	69.68a	81.08a	76.67a	0.84a	6479.82a
			Irrigation × Selenium			
I0 Se0	141.81 ab	76.66a	80.19 b	77.32a	0.92a	7656.73a
I0 Se1	137.46 b	71.55bc	81.15 ab	78.48a	0.79bc	6616.50b
I1 Se0	120.51c	57.99d	81.52 ab	76.18ab	0.88ab	6496.14b
I1Se1	118.67 c	60.14d	83.04 ab	79.22a	0.88ab	6591.00b
I2 Se0	143.59 ab	74.42 ab	75.45c	73.17b	0.80bc	6019.26b
I2 Se1	144.72 ab	72.49abc	75.75c	79.84a	0.85ab	6462.83b
I3 Se0	145.55a	69.25 c	76.45 c	68.47c	0.71c	5386.99c
I3 Se1	142.73 ab	74.53ab	84.38a	69.16c	0.83ab	6369.29b

Means in each followed by the similar letters are not significantly different at 5% probability level using Duncan, Multiple Range test

Tab. 4. Mean comparisons plant characteristics of maize in main effects of microelement fertilizer, interaction of irrigation × microelement fertilizer and selenium× microelement fertilizer

Treatments	Plant height (cm)	RWC_{V8} (%)	RWC_{R2} (%)	RWC_{R4} (%)	WUE ($kg.m^{-3}$)	Grain yield ($kg. ha^{-1}$)
			Microelement			
M0	139.34 a	68.87a	78.30b	75.81a	0.85a	6618.21a
M1	134.42a	70.39a	81.19a	74.60a	0.81a	6281.47b
			Microelement × Irrigation			
M0 I0	139.14 bc	74.97a	78.79bc	80.56a	0.83a	6850.14ab
M1 I0	150.13a	73.25a	82.55ab	75.23bc	0.88a	7320.73a
M0 I1	121.34d	57.75b	79.93bc	78.11ab	0.90a	6768.25ab
M1 I1	117.83d	60.38b	84.63a	78.29ab	0.86a	6439.25bc
M0 I2	140.78bc	72.49a	`74.46d	73.91cd	0.85a	6422.27bc
M1 I2	137.52 c	74.41a	76.74cd	79.10a	0.80a	6059.82c
M0 I3	146.10ab	70.28a	80.02bc	70.65d	0.84a	6432.19bc
M1 I3	142.18bc	73.5a	80.82ab	70.99d	0.70b	5324.09d
			Microelement × Selenium			
M0 Se0	142.84a	67.60b	77.09b	74.61ab	0.86a	6664.41a
M1 Se0	132.88b	70.14ab	79.72b	72.96b	0.79a	6175.33b
M0 Se1	135.85b	71.56a	79.51b	77.00a	0.85a	6572.01ab
M1 Se1	135.95b	69.21ab	82.65a	76.35a	0.83a	6387.62ab

Means in each followed by the similar letters are not significantly different at 5% probability level using Duncan, Multiple Range test

height is related to two phenomena, an increase in node number and an increase of inter-node length and these are strongly affected by drought stress (Wright *et al*., 1988). Water deficit stress decreased grain yield 6% in stage V8, 19.7% in stage of blister and 16.9% in stage of grain filling as compared with control. Decrease in grain yield can due to reduced leaf, silk and grain kernel expansion, reduced assimilate flux to growing organs, accelerated leaf senescence, delayed silk growth and greater ear and kernel abortion (Bassetti and Westgate, 1993). Also result of this research is parallel with results of other researchers (Bassetti and Westgate, 1993; Schussler and Westgate, 1995).

Effect of selenium on relative content Water at R2 and R4 stages was significant but on relative content Water

Tab. 5. Mean comparisons of plant characteristics of maize in interaction effects of threefold irrigation× selenium microelements fertilizer treatments

Irrigation	Selenium	Microelement	Plant height (cm)	RWC_{V8} (%)	RWC_{R2} (%)	RWC_{R4} (%)	WUE ($kg.m^{-3}$)	Grain yield ($kg. ha^{-1}$)
I0	Se0	M0	143.36ab	78.40a	77.60c-f	81.27a	abc88/0	7336.55ab
I0	Se0	M1	140.25ab	74.93abc	82.79abc	73.36cde	0.96a	7976.91a
I0	Se1	M0	134.92bc	71.55abc	79.99b-e	79.86ab	0.77bc	6790.73 bc
I0	Se1	M1	140.01ab	71.56abc	82.32abc	77.10abc	0.81bc	6628.55bc
I1	Se0	M0	126.16cd	53.33f	75.96def	78.04abc	0.90ab	6799.52bc
I1	Se0	M1	114.86e	62.65de	87. 09a	74.33bcd	0.86abc	64.33.48bcd
I1	Se1	M0	116.53e	62.16de	83.91ab	78.18abc	0.90ab	6736.97bc
I1	Se1	M1	120.82de	58.11ef	82.18abc	80.25a	0.85abc	6445.03bcd
I2	Se0	M0	150.76a	70.79bc	75.88def	67.74fg	0.85abc	6448.16bcd
I2	Se0	M1	136.42b	78.04ab	75.03ef	78.61abc	074cd	5590.36d
I2	Se1	M0	151.81a	74.20abc	73.05f	80.08ab	0.85abc	6396.38bcd
I2	Se1	M1	138.62b	70.79bc	78.45b-f	79.59ab	0.86abc	6529.28bcd
I3	Se0	M0	151.08a	67.88cd	78.94b-f	71.41def	0.80bc	6073.43cd
I3	Se0	M1	140.01ab	70.62bc	73.96f	65.53g	0.63d	4700.55e
I3	Se1	M0	141.12ab	72.67 abc	81.09bcd	69.89d-g	0.88abc	6363.96bcd
I3	Se1	M1	144.35ab	76.39ab	87.67a	68.44efg	0.78bc	5947.62cd

Means in each followed by the similar letters are not significantly different at 5% probability level using Duncan, Multiple Range test at V8, water use efficiency was and grain yield not significant, however with using selenium mentioned traits, were increased (Tab. 3). This is important from viewpoint of quantity and quality for consumption human and animals. Result of this research is parallel with results of Pennanen *et al.* (2002), those reported that plant growth promoted by selenium is due to increased starch accumulation in chloroplast. Selenium seemed to improve pollen survival and fertilization (Seppnen *et al*., 2003). Xue *et al.* (2001) showed that enhancement of photosynthesis and a decrease in leaf senescence increases assimilate production and towards seed and as result seed yield increases.

Results of two fold interactions water deficit stress and selenium on relative content Water at V8 and R2 stages, water use efficiency and grain yield was significant but on Plant height and relative content Water at V4 not significant (Tab. 2). Using selenium both in water optimum and water deficit stress increased relative content Water at R2 and R4 stages (Tab. 3). Selenium seemed that can regulate the water status of plant under condition of water deficiency and thereby has a protective effect of water stress (Kuznetsov *et al*., 2003). Highest grain yield (7656.73 $kgha^{-1}$) was obtained from control treatment (Without stress and without Selenium) which showed significant differences in compared to other treatments. Using selenium in water deficit stress condition increased all of traits except plant height as compared to treatment without using selenium (Tab. 3). It has been reported that selenium prevents chlorophyll degradation under stress conditions (Seppnen *et al*., 2003).

It has been reported that selenium has antioxidant properties and under conditions of environmental stress, especially water stress, it can scavenge reactive oxygen species (Xue *et al.*, 2001). Glutathione proxidase is an important enzyme in antioxidant defense systems of plant. Selenium is an essential element in the structure of this enzyme (Timothy, 2001). Least grain yield was obtained from treatment of water deficit stress in grain filling stage and without Selenium application (Tab. 3). This might be indicative of plant sensitivity due to no protection factor under water stress.

Application of microelements decreased grain yield significantly at 5% level (Tab. 1). This may be related to antagonistic interaction of microelements to each other. In maize, with copper application alone and along with iron and manganese decreased grain yield (Himayatullah and Khan, 1998).

Using microelements in water optimum conditions increased traits measured as compared to without microelements but in water deficit stress conditions in all growth stages, traits of measured were decreased. Using microelements in water deficit stress condition increased traits of relative content water at V8, R2 and R4 stages but traits of water use efficiency, plant height and grain yield decreased as compared to treatment without using microelements (Tab. 4). Presumable in water deficit stress condition was decreased remobilization microelements.

Three fold interactions experimental factors on relative content water at V8, R2 and R4 stages was significant but on water use efficiency, plant height and grain yield was not significant. Using of along selenium and microelements under water deficit stress conditions in vegetative stage (V8) and reproductive stage (R2 and R4 stage) increased relative content water at three stages in compared to without using this elements in water stress conditions (Tab. 5). The highest amounts of grain yield (7976.91 $kgha^{-1}$ obtain from treatment of water optimum conditions+without selenium+with microelements (Tab. 5). Using selenium and microelements under water deficit stress conditions in blister stage (R2) increased grain yield in compared to without using this elements in water stress conditions (Tab. 5). Presumable in the end of growth period that increased stress conditions, and decrease mechanism of defensive plant, selenium and microelements with take part in biological activity of cells, induced health protection and permanent in function of membranes.

Conclusions

Improvements in maize drought tolerance are therefore vital for maintaining local and global food security. In general, plants tolerated unfavorable environmental conditions by changing their morphology as living indices. Results show that selenium foliar applications can improve yield under conditions of drought stress and it may be recommended for lands in arid semi- arid regions. Other microelements such as Fe, Zn, Cu, Mg and Mn also play their role as cofactors in biological activities the structure of plant therefore when plants are deficient of these elements, increased sensitivity to environmental stresses. Using microelements in water optimum condition increased traits of measured as compared to without microelements but in water deficit stress condition in all growth stages traits were decreased. Using of selenium and microelements in water deficit stress condition in vegetative growth stage and dough stage increased yield as compared to without using this elements in water stress condition. The combined results of these studies indicate that by using selenium and microelements under water stress can produce suitable quantitative and qualitative as compared to without using this elements.

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