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EFFECTS OF POTASSIUM AND IRON ON YIELD OF CORN (*ZEA MAYS* L.) IN DROUGHT STRESS

K. ZARE[1], F. VAZIN[1]*, M. HASSANZADEHDELOUEI[1]

*E-mail: farshidvazin@gmail.com

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ABSTRACT. In hot and arid regions, drought stress is considered as one of the main reasons for yield reduction. To study the effect of drought stress, Iron and potassium spray on the yield and yield components of corn, an experiment was carried out during the crop seasons of 2010 and 2011 on Abosaeid research field of Mahvellat as a split factorial within randomized complete block design with three replicates. The main plots with irrigation factor and three levels were considered: irrigation per 6, 9 and 12 days. Subplots were considered with and without Iron and potassium spray. The irrigation reduced the grain yield in irrigation per 12 more than other stages. Irrigation effects significantly on chlorophyll value, leaf relative water content, stem, ear and leaves dry weight, number grain in ear and row, number row in ear, unfilled seed percentage and thousand grains weight. Iron increased the seed yield and yield component, except unfilled seed percentage and SPAD. Using K, as compared with control treatment, causes the increase of grain yield, 1000 grains weight and number grain in ear 16.5, 9 and 5.5% respectively. Potassium could somewhat reduce the impact drought stress on corn.

Key words: Drought tress; Potassium; Iron; Spray; Corn.

INTRODUCTION

Drought is one of the factors which threaten agriculture products in most parts of the world (Abolhasani and Saeidi, 2004; Banziger *et al.,* 2002). It causes stress in plants and is not only caused by the reduction of rainfalls and great heat, but in the cases where there is moisture in the soil, this moisture cannot be used for plants for some reasons such as excessive soil salinity or soil frost, and plants will be stressed (Baydar and Erbas, 2005). Drought and water shortage are considered an objective reality. In the past, water crisis was not as significant as today, since the population was less, but with the population increase by about six times and the need for more food during the last 100 years, the incidence of this

[1] Islamic Azad University, Gonabad Branch, Gonabad, Iran

crisis has become more evident than the past (Chimenti *et al.,*2002).

Potassium plays a vital role in: photosynthesis, translocation of photosynthates, protein synthesis, control of ionic balance, regulation of plant stomata and water use, activation of plant enzymes and, many other processes (Reddya *et al.,* 2004). Potassium is not only an essential macronutrient for plant growth and development, but also is a primary osmoticum in maintaining low water potential of plant tissues. Therefore, for plants growing in drought conditions, accumulating abundant K+ in their tissues may play an important role in water uptake along a soil–plant gradient. In general, K+ is accumulated in response to soil water deficits, while Na+ is accumulated under saline conditions (Glenn *et al.,* 1996). The accumulation and release of potassium by stomatal guard cells lead to changes in their turgor, resulting in stomatal opening and closing (Fischer and Hsiao, 1968). In water stressed plants, increased abscisic acid (ABA) levels are known to stimulate the release of potassium from guard cells, giving rise to stomatal closure (Assmann and Shimazaki, 1999). Numerous studies have shown that the application of K fertilizer mitigates the adverse effects of drought on plant growth (Andersen *et al.,* 1992; Sangakkara *et al.,* 2001). Potassium increases the plant's drought resistance through its functions in stomatal regulation, osmoregulation, energy status, charge balance, protein synthesis, and homeostasis (Marschner, 1995). In plants coping with drought stress, the accumulation of K+ may be more important than the production of organic solutes during the initial adjustment phase, because osmotic adjustment through ion uptake like K+ is more energy efficient (Hsiao, 1973). Fusheing (2006) has revealed that lower water loss of plants well supplied with K+ is due to a reduction in transpiration which not only depends on the osmotic potential of mesophyll cells but also is controlled to a large extent by opening and closing of stomata.

Under water shortage conditions, the effectiveness of fertilizers decreases, especially if consumption of these fertilizers is not compatible with the vegetative growth of plants. However, it should be noted that soils of Iran, which are categorized under the calcareous soils, due to drought stress, salinity, being calcareous, highly acidity, having low contents of organic materials, continuing drought, and continuing unbalanced consumption of fertilizers, iron and potassium contents are too low. Therefore, the plants which grow in such soils are mainly suffered from shortage of iron and potassium and shortage indications are observed in them (Jaleel *et al.,* 2009).

The aim of our study was, therefore, to determine the interactive effects of water availability, Fe and K fertilizer rate on the grain yield and yield components of maize in Iran.

MATERIAL AND METHODS

This test was conducted in agricultural year of 2011 in split plot style in completely randomized block design in three replicates in the Abosaeid research field of Mahvellat (34°54′ N 58°50′ E and height of 940 m). The soil of experimental plot was silt, pH 7.71, EC 1.92 dS m^{-1}, organic carbon 0.2%, available nitrogen 0.02%, phosphorus 0.6 % and potassium 0.2 %. Experiment treatments including irrigation were carried out at three levels of irrigation per 6 days, irrigation per 9 and 12 days in main plots. Subplots were considered with and without potassium and iron spray. For foliar application of iron and potassium were used from chelate source of iron and liquid potassium.

Generally, there were 36 subsidiary plots with the surface area of 20 m^2 (5 meters NS and 4 meters WE), which were divided into two rows. The planted item was of SC704 type. Planting was performed on 26 May as dry planting with the density of 7.5 plants per square meter. According to the results obtained from the soil analysis, the required fertilizer was added to the farmland. To do so, 200 kg of urea, 150 kg of super phosphate and 100 kg of potassium soleplate per hectare were added to the soil. In order to calculate the seed yield, all the ears picked from one square meter were distributed and threshed manually; at that moment, the humidity was about 14%. The biological yield (biomass) in each plot was performed after picking the plants from one square meter and counting all the ears (number of ears per surface unit). Five plants were selected randomly and the weight of thousand grains and each ear, number of grains per ear, number of rows per ear, number of grains per row, length of the ear, plant and stem height, diameter of the stem, chlorophyll value, leaf area index, leaf relative water content, stem, ear and leaves dry weight and unfilled seed percentage were calculated. Analyzing data and drawing graphs were carried out by SAS and EXCEL software. Comparisons of average related to the drought stress and spray were carried out through Duncan experiment.

RESULTS AND DISCUSSION

Seed yield

Averaged across the Fe and K rates, the grain yield of drought stressed (irrigation at 9 and 12 days) maize was 46% lower than that of irrigation at 6 days (*Table 1*).

The significant water regime × K rate interaction effects on grain yield (*Table 1*). Indicate that the grain yield increases resulting from N fertilization depended on the water regime (*Table 1*). Similar effects were found in previous studies (Pandey *et al.,* 2000). In the present study, K supply resulted in maximum grain yield under irrigation at 9 days, whereas without K resulted in minimum grain yield under irrigation at 12 days (*Fig. 1a, b*).

The results of analyzing data variance showed the interaction between drought stress and Fe spraying on seed yield to be significant (P <0.01) (*Table 1*). The highest seed yield was related to the lack of application of Fe in the irrigation at 9 days conditions with 680.25 g m^{-2}, and its lowest value was related to the application of zinc in irrigation at 9 days with 250.2 g m^{-2} (*Fig. 1a*). Based on *Fig. 2*, the most level of seed yield has been earned from the use of iron and potassium together in the condition of without drought stress. But in drought stress condition, the use of iron and potassium together can't have any effect on the seed yield.

Yield components

Interaction of moisture stress and iron and potassium spray on yield components was significant ($p<0.01$) (*Table 1*). Applying iron and potassium at the same time under irrigation per 6 days condition, the maximum weight of thousand kernels, number of grains per ear and number of rows per ear were achieved. Under stress treatment at the irrigation per 9 days, iron spray increased number of seeds per ear, weight of thousand kernels and number of rows per ear significantly as 9.7, 3.5 and 4.4%, respectively (*Table 1*). In all stress treatments, except stress at the irrigation per 12 days, potassium spray increased yield components significantly (*Table 1*). In irrigation per 6 days treatment, potassium spray increased thousand kernels weight as 5.8% . In stressed treatment at the irrigation per 9 days, potassium spray increased number of rows in ear and number of seeds in row as 17.4% and 8.3%, respectively. Iron and potassium spray increased number of rows per ear, number of seeds per ear and thousand kernels weight significantly as 12.6%, 7.5%, and 8.8%, respectively, as compared with non-spray (*Table 1*).

Biological yield

The interaction of drought stress and iron and potassium spray on the biological yield was significant ($p<0.01$) (*Table 1*). Simultaneous application of iron and potassium under irrigation per 6 days conditions and application of iron under irrigation per 6 days conditions were 1593.08 and 1564.08 g*m^{-2}, respectively. Considering a statistical level and treatments of non-application of iron and potassium elements at the irrigation per 12 days and their individual application under the same stress conditions, the maximum biological yield produced the least amount of biomass yield. Under the stress treatment at the irrigation per 12 days, biological yield was increased significantly by spraying iron and potassium (*Table 1*). On iron spray, the increase (15%) was more than potassium (12.6%). Under irrigation per 6 days conditions, iron and potassium spray significantly increased the biological yield for 13% (*Table 1*).

Plant Relative Water Content (RWC)

RWC content was significantly affected by irrigation and K supply (*Table 1*). Under irrigation per 9 and 12 days, RWC was decreased significantly about 18.8 and 50.6%, respectively, less than control (*Table 1*).

Table 1 - Main effects of drought stress and iron and potassium application on quality and quantity characteristics of corn (*Zea mays* L.)

Treatment	GY ($g\ m^{-2}$)	BY ($g\ m^{-2}$)	GN (g)	1000 GW	GNR	RNE	UG %	RWC %	SPAD %
Irrigation									
I_6	1063.33a	1857.35a	372.81a	305.28a	25.41a	14.62a	11.43a	90.00a	57.15a
I_9	401.83b	1005.94b	233.79b	217.41b	17.92b	13.03b	27.09b	73.48b	39.86b
I_{12}	170.42c	642.88c	141.46c	160.75c	13.46c	10.48c	47.21c	44.67c	27.50c
Fe rate									
Fe_0	514.27b	1112.87b	237.79b	223.92b	18.52b	12.38b	30.16a	68.30a	41.09a
Fe_1	576.09a	1224.58a	260.93a	231.70a	19.34a	13.04a	26.99b	68.88a	41.91a
K rate									
K_0	484.50b	1067.73b	229.75b	221.09b	18.18b	12.22b	30.75a	67.90b	40.51b
K_1	605.87a	1269.72a	268.97a	234.53a	19.68a	13.20a	26.40b	69.28a	42.49a
Significant[1]									
Irrigation	**	**	**	**	**	**	**	**	**
Fe	**	**	**	**	**	*	**	ns*	
K	**	**	**	**	**	**	**	**	**
I×Fe	**	**	**	ns	**	**	**	ns	ns
I×K	**	**	**	ns	*	**	**	ns	ns
Fe×K	**	ns	**	**	**	**	ns	ns	ns
I×Fe×K	ns	ns	ns	ns	**	**	ns	ns	ns

[1]Significant effects are denoted as: ns, *, **, non significant or significant at $P \leq 0.05$, 0.01, respectively.

I_6: irrigation per 6 days; I_9: irrigation per 9 days; I_{12}: irrigation per 12 days. Fe_0: without Fe, Fe_1; with Fe, K_0; without K, K_1; with K; GY: grain yield; BY: biological yield; GN: number of grain in ear; 1000 GW: 1000 grain weight; GNR: number of grain in row; RNE: number of row in ear; UG: unfilled grain; RWC: relative water content in grain-filling stage; SPAD: chlorophyll content in grain-filling stage.

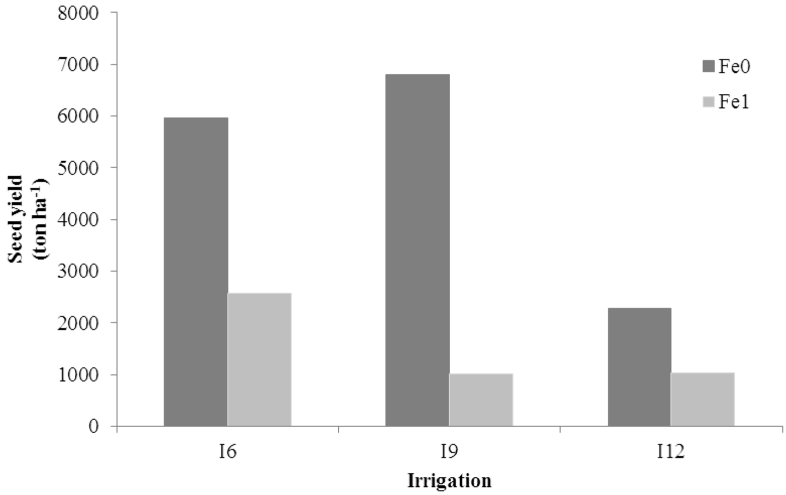

Figure 1a - Effect Fe (top) on seed yield under irrigation

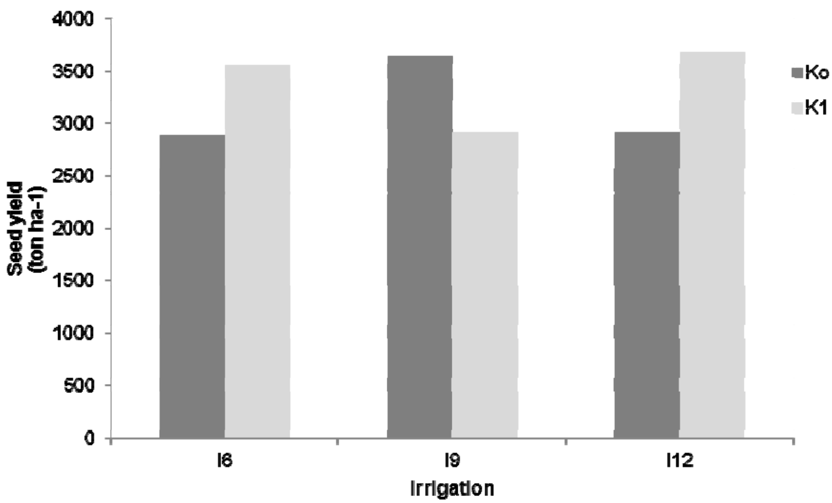

Figure 1b - Effect K (bottom) on seed yield under irrigation

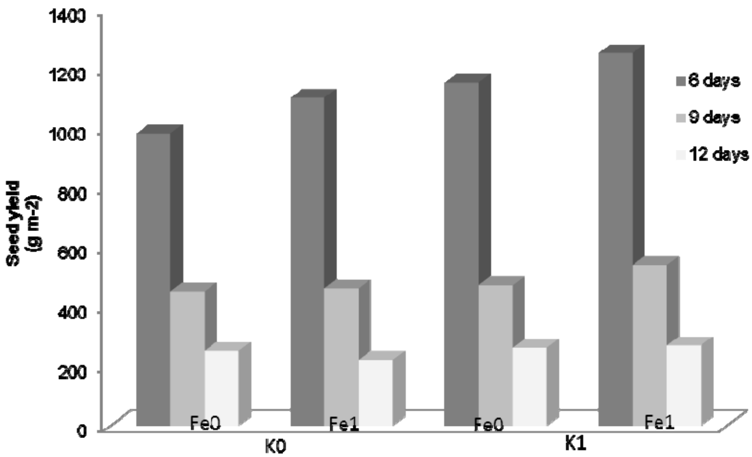

Figure 2 - Interaction irrigation, K and Fe on seed yield of corn

Castro *et al.* (2006) reported that RWC is between 80.4 and 91.7 in ideal conditions (full irrigation) in new lines of sunflower, while it is between 59.5 and 80.7 in the stress conditions. Reduction of leaf relative water content indicates the decrease of swelling pressure in plant cells and reduces growth. As water is removed from soil and since it will not be replaced, the water potential will be dropped at root area and if resistance of a stomata without a is stable in the plant, plant water potential will be reduced in order to maintain the rate of transpiration (Karam *et al.,* 2006). K spraying, RWC was increased significantly about 2% more than without K (*Table 1*).

Chlorophyll index

The effect of drought stress on chlorophyll index was significant ($P<0.01$) and it is consistent with the results of Yari *et al.* (2005), suggesting that moisture stress reduces leaf chlorophyll content. Reviewing mean comparisons showed that in drought stress levels, the highest chlorophyll index was obtained in irrigation per 6 days treatment (57%) and the lowest chlorophyll index was obtained in irrigation per 12 days (27.5%). According to the mean comparison results, chlorophyll index increased significantly with Fe and K spraying about 2 and 5%, respectively (*Table 1*). The highest amount of chlorophyll index was obtained in the spraying of K with 42.49% (*Table 1*). Chlorophyll maintenance and consequently photosynthesis durability in stressful conditions are among physiological indicators of stress resistance (Zhang *et al.,* 2006; Jiang and Huang, 2002).

CONCLUSION

According to *Fig. 1(a,b)*, iron application isn't able to decrease the effect of drought stress irrigation per 9 and 12 days and even with the use of iron, such effects have gotten more serious. But with the use of potassium these effects in drought stress condition have reduced significantly. According to this study, in drought stress condition, the use of potassium is more effective than iron.

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