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Original Article

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EFFECT OF IRON ON YIELD OF CORN (*ZEA MAYS* L.) IN DROUGHT STRESS

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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 spray on the yield and yield components of corn, an experiment was carried out during the crop seasons of 2013 on research Farm in Faizabad of Iran, as a split plot within randomized complete block design with three replications. The main plots with irrigation factor and four levels were considered: level A) 50 ml evaporation from pan evaporation; level B) 100 ml evaporation from pan evaporation; level C) 150 ml evaporation from pan evaporation and level D) 200 ml evaporation from pan evaporation. Sub plots were considered with iron spray in three levels, included level A) 80 g/ha, level B) 130 g/ha and level C) 180 g/ha. The drought stress reduced seed yield, the 1000-kernels weight (TKW), the number of seeds per ear, the number of seeds per row in ear, the number of rows per ear about 39%, 6%, 31%, 14% and 27% less than control treatment, respectively. Using iron, as compared with control treatment, causes the increase of 1000-kernels weight from 295 to 311 g and the increase of seed yield from 5188 to 7078. The results obtained from the present research showed that iron spray has fairly improved the effects caused by drought stress.

Keywords: RWC; pan evaporate; micronutrients; chlorophyll index.

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; Borrell *et al.,* 2008). 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

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population increase by about six times and the need for more food during the last 100 years, the incidence of this crisis has become more evident than the past (Chimenti *et al.,* 2002; Flagella, 2002)

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; Sharafi *et al.,* 2002).

One of the most important effects, which accompany moisture, is that with the decrease of moisture in soil, movement of elements, such as iron and zinc, in soil solution decreases. This limits the growth of root and plants face additional shortage of this element (Chimenti *et al.,* 2002). It should be noted that plants, animals and humans need a little amounts of iron and zinc (Zhang *et al.,* 2006; Agele *et al.,* 2007). Jiang and Huang (2002) reported that the yield and its components in wheat are increased due to the effects of iron and zinc on the amount of chlorophyll and concentration of abscisic acid.

The increase of chlorophyll increases yield through the increase of photosynthesis. Although plants need a little amount of zinc, if sufficient amount of this element is not available, plants suffer physiological stresses resulted from inefficiency of various enzyme systems and other metabolic functions related to zinc (Baydar and Erbas, 2005; Babaeian *et al.,* 2010).

Richards *et al.* (2002) reported that lack of zinc in microelements creates the major problems for producing crops, especially in soils of dry and semiarid regions with shortage of water. Therefore, suitable usage of this element in dry and semi-arid regions is of crucial importance to improve the growth and yield of plants in these regions (Salehi *et al.,* 2004; Banks, 2004; Erdem *et al.,* 2006).

MATERIALS AND METHODS

This study was conducted as a split plot experiment with three repetitions during the crop seasons of 2013 at Research Farm in Faizabad of Iran. The sample water was C3S1 in terms of international classification. Soil analysis was acidity equal to 7.71, absorb potassium to 2.65, absorb phosphor equal to 6.12, organic carbon to 0.2, total Nitrogen 0.02. soil texture included clay, sand and silt 23.5, 24 and 52.5, respectively. In this experiment, four levels of irrigation, including level A) 50 ml evaporation from pan evaporation, level B) 100 ml evaporation from pan evaporation, level C) 150 ml evaporation from pan evaporation and level D) 200 ml evaporation from pan evaporation were as main plots and three levels of iron Kallat, including level A) 80 g/ha, level B) 130 g/ha, and level C) 180 g/ha were as the subplots.

The irrigation circuit was carried out every seven days until taselling stage and then irrigation was carried out under treatment with use pan evaporate. Each of the experimental plots included five rows of planting with 75 cm distance from each other, as bed and dole. The length of each experimental plot was 5 m. The distance between the subplots was 2 m and the space between the blocks was 3 m. Operations of land preparation were conducted a week before planting through plowing, disc, leveler and implementing project plans. Before planting, 100 kg of potassium sulfate, 150 kg of triple super phosphate and 250 kg of urea fertilizer were used during water shortage.

In this experiment, the number of 704 with density of 85000 plants/ha was used, in which the density was considered high when planting and the desired density was achieved by thinning after emergence and full deployment of the plant. Seed planting was manually performed through dry farming. After the emergence, various parameters of some growth traits of phonological stages and morphological and physiological characteristics of plant were measured every two weeks during the test.

All required sampling from the second half of each plot was conducted through observing the margin effect and the first half of each plot remained intact until the end of the growth season to compare the final yield. After the physiological maturity, five shrubs were randomly picked from the second half of each plot and were used to measure the yield components. At the end, after collecting the required data, data analysis processes were conducted using the software SAS and Excel.

RESULTS AND DISCUSSION

Seed yield

The results of analyzing data variance showed the interaction between drought stress and Iron on seed yield to be no significant (*Table 1*). Seed yield decrease significantly in all stress treatments (*Table 1*). In the 200 ml evaporation from pan evaporation treatment, the decrease was 60%, compared to 50 ml evaporation from pan evaporation treatment. Iron with concentration of 180 g/ha increased seed yield by 5%, compared to 80 g/ha (*Table 1*). Drought stress reduces the transfer of nutrients from leaves to seeds, and given that drought accelerates maturation of seeds, this process will also help to decrease seed yield by reducing photosynthesis (Erdem *et al.,* 2006; Jasso de Rodriguez *et al.,* 2002).

Yield components

Drought stress and iron on seed weight was significant, but the interaction between drought stress and iron on this trait was not significant (*Table 1*). The lowest seed weight (276 g) was observed in the 200 ml evaporation from pan evaporation treatment that was 13% lighter than seed weight in full irrigation treatment. As *Fig. 1* shows, grain's weight importance is increased. As a result, if iron is used, grain's weight importance will be increased as compared with the number of grains in determining the grain yield. The results of so many studies show that grain weight can be influenced by irrigation interval (Thalooth *et al.,* 2006; Kafi and Rostami, 2007). Also, the maximum seed weight was obtained from treatment through iron with concentration of 180 g/ha (311 g). The positive effect of iron on seed weight has been also reported by other researchers (Baybordi, 2006; Banks *et al.,* 1982.

Table 1 - Variance analysis and means compares of drought stress and Fe application on quality and quantity characteristics of corn (*Zea mays* L.).

Treatment SPAD	GY ($g\ m^{-2}$)	BY ($g\ m^{-2}$)	GN	1000 GW (g)	RWC (31DAS)	RWC (42DAS)	SPAD (30DAS)
Irrigation T_1	891.0a	1999.7a	607.4a	318.8b	51.2a	63.3a	51.4a
Irrigation T_2	860.0a	1931.4a	522.3b	332.1a	45.9b	64.4a	48.2b
Irrigation T_3	401.0b	1440.7b	359.0c	285.9c	47.2b	52.3b	43.3c
Irrigation T_4	354.0b	1388.2b	361.0c	276.2c	50.2b	49.6b	42.3c
Fe rate Fe_{80}	518.0c	1546.0c	449.5b	295.1c	45.3b	55.3	45.2
Fe rate Fe_{130}	654.0b	1715.3b	452.0b	302.3b	49.2a	56.1	46.1
Fe rate Fe_{180}	707.0a	1807.0a	486.3a	311.3a	49.3a	59.8	48.9
Significant[1]							
Irrigation	**	**	**	**	**	**	**
Fe rate	**	**	*	**	*	ns	ns
I×Fe	**	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. T_1: 50 ml evaporation from pan evaporation, T_2: 100 ml evaporation from pan evaporation T_3: 150 ml evaporation from pan evaporation, T_4: 200 ml evaporation from pan evaporation. Fe_{80}: 80 g iron in ha, Fe_{130}: 130 g iron in ha, Fe_{180}: 180 g iron in ha; GY: Grain yield, BY: Biological yield, GN: Number of grain in ear, 1000 GW: 1000 grain weight, RWC: Relative water content in 31 and 42 days after sowing; SPAD: Chlorophyll content in 30 days after sowing.

The effect of drought stress and iron on the number of seeds per ear was significant, whereas the interaction between drought stress and iron was not significant (*Table 1*). The lowest number of seeds per ear was given in 150 ml evaporation from pan evaporation treatment (*Table 1*). which was 40% less than control treatment (50 ml evaporation from pan evaporation). The number of seeds per ear had a significant impact on yield of corn and will be affected by growth environmental conditions more than seed weight.

As *Fig. 2* shows, when iron is not used, the relationship between number of grains per ear and yield of grain is positive (R2=0.35). With the increase of number of grains, the yield of grain increases and *vice versa*; however, iron apply decreases the effect of number of grains on the grain yield (R2=0.06). These results are consistent with the results obtained by Göksoy *et al.* (2004) on the effect of drought stress on the number of seeds per ear of *Zea mays*. This conclusion has been similarly observed about the effect of drought stress on the number of seeds per bag of rapeseed and the number of seeds by sunflower (Castro *et al.,* 2006; Yahyavi Tabriz and Sadrabadi Haghighi, 2004).

Iron had also a significant impact on the increase of the number of seeds per ear, in a way that iron with concentration of 180 g/ha increased the number of seeds per ear by about 7% (*Table 1*). The results of experiments by Agele *et al.* (2007) also indicate the positive effect of micronutrient fertilizers, such as iron sulfate on the number of seeds regarding the sunflower. Moreover, some reports have been presented on the positive role of the use of Iron sulfate fertilizer on the number of seeds generated in the shrub of wheat, canola and sunflower.

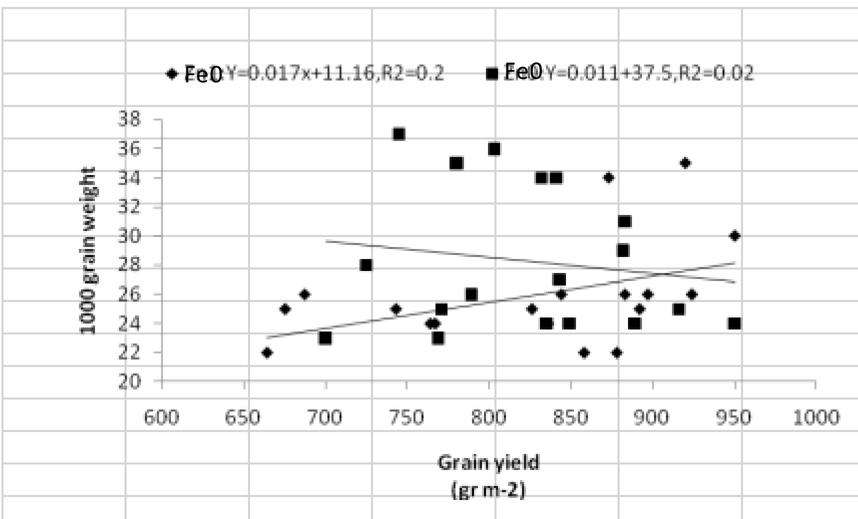

Figure 1 - Effect Fe on relationship between grain yield and 1000 grain weight in corn

Biological yield

The effect of water shortage and Iron on the biological yield that represents the accumulated dry matter in shoots at harvest time is significant, while their effect on the biological yield was not significant (*Table 1*). With increase of drought stress, a significant reduction was observed in biological function. These results confirmed the findings of Richards *et al.* (2002) suggesting the reduction of biological yield caused by drought stress. Mean comparison results showed that drought stress in the eight-leaf stage reduced the biological yield by 15%, compared to full irrigation. The reason for increase of dry matter production in plants under full irrigation treatment was more expansion and better durability of the leaf area, which created a complete physiological source for more use of incoming light and dry matter production. Comparisons of results in different levels of iron showed that biological yield was raised with increase of iron apply (*Table 1*). Considering that the effect of drought stress and iron on biological yield was not significant, but the mean comparison results showed that iron with concentration of 180 g/ha in desirable irrigation conditions was considerably superior in terms of dry matter production, compared to the other treatments, while in drought stress conditions, biological yield changes caused by the increase of iron were not significant.

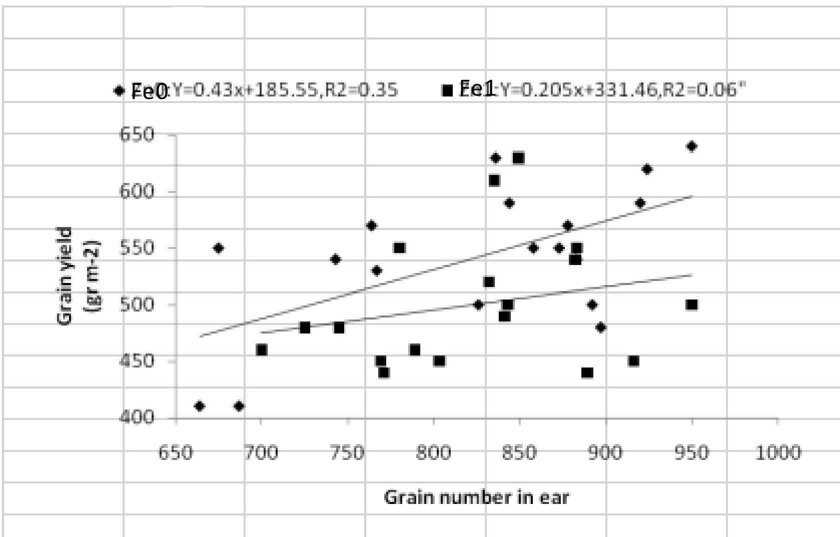

Figure 2 - Effect Fe on relationship between grain yield and grain number in ear of corn

Plant relative water content (RWC)

Effects of drought stress, as well as iron on relative water content, became significant 31 and 42 days after planting ($p < 0.05$), while the interaction of drought stress and iron did not become significant (*Table 1*). Leaf relative water content decreased with increase of drought stress (*Table 1*). The highest rate of relative water content (31 days after planting) was obtained in 100 ml evaporation from pan evaporation treatment (64%) and its lowest value was obtained in 200 ml evaporation from pan evaporation treatment (49%). The highest plant relative water content (42 days after planting) was obtained 100 ml evaporation from pan evaporation treatment, which was in the same statistical group as 50 ml evaporation from pan evaporation treatment. Relative content is in fact the right tool for yield or yield component in drought stress selection. As it is revealed from the results, plant relative water content decreases with increase of drought stress and this reduction was reduced by 8% in the first measurement in which the plant was stressed in vegetative stage and it was reduced by 13% in the first measurement in which the plant was stressed in the reproductive stage. 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. According to the results, the reduction of relative content in drought stress conditions in the reproductive stage was more than when the plant was under stress in the vegetative stage. 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 is stable in the plant, plant water potential will be reduced in order to maintain the rate of transpiration (Karam *et al.,* 2007; Soriano et al, 2004).

Mean comparison results in iron also showed that the highest relative content was obtained in concentration of 180 g/ha (59.63%) (*Table 1*), which increased 7%, compared with 80 g/ha treatment. Comparison results of mean of interactions between drought and iron suggested that at the level of 50 ml evaporation from pan evaporation (control), iron increased relative water content. While in the levels of drought stress, mean did not follow a specific order. These results showed that in drought stress levels, the increase in the concentration of iron has no effect on relative water content. However, results of the interaction showed that relative water content decreased with increase of drought stress at all levels of iron (*Table 1*).

Chlorophyll index

The effect of drought stress on chlorophyll index was significant ($p < 0.01$) (30 days after planting) and it is consistent with the results of Yari *et al.* (2005), suggesting that moisture stress reduces leaf chlorophyll content. However, the effect of the interaction between drought stress and Iron was not significant (*Table 1*). Reviewing mean comparisons showed that in drought stress levels, the highest chlorophyll index was obtained in level of 50 ml evaporation from pan evaporation treatment (51.9%) and the lowest chlorophyll index was obtained in level of 200 ml evaporation from pan evaporation (42.3%). According to the mean comparison results, chlorophyll index increased with iron, although it was not statistically significant. The highest amount of chlorophyll index was obtained in concentration of 180 g iron/ha (*Table 1)*.

Side effects of stress were decreased with increase of iron. Survey results showed that drought stress reduced chlorophyll index by 7%, compared to control. Chlorophyll maintenance and consequently photosynthesis durability in stressful conditions are among physiological indicators of stress resistance (Zhang *et al.,* 2006; Jiang and Huang, 2002).

CONCLUSIONS

When iron is not used, the relationship between number of grains per ear and yield of grain is positive (R^2=0.35). With the increase of number of grains, the yield of grain increases and vice versa; however, Iron apply decreases the effect of number of grains on the grain yield (R^2=0.06). Grain's weight importance is increased. As a result, if iron is used, grain's weight importance will be increased as compared with the number of grains in determining the grain yield.

Overall, the results of this experiment showed that *Zea mays* parameters were strongly affected by drought. This result was obtained because drought stress was followed by reduction of different traits and had also a negative effect on many yield components and eventually quantitative yield of seed. In line with the results, the plant yield response to the moisture deficit stress is different according to the stage in which the plant is stressed.

According to the results, level of 200 ml evaporation from pan evaporation had the greatest negative influence on *Zea mays* yield. Reduction of chlorophyll index and plant relative water content also reduced seed yield. In addition, the results showed that application of iron reduced the side effects of stress. Overall, the results of this study showed that the use of iron is one of the important crop techniques in arid and semiarid areas to reduce the effects of stress caused by lack of moisture. Therefore, it seems essential to particularly consider this important nutritional element in the programs of fertilizer recommendations and soil fertility management in these areas.

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