

EFFECT OF ZINC SULFATE ON QUANTITATIVE AND QUALITATIVE CHARACTERISTICS OF CORN (*ZEA MAYS*) 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 and zinc spray on the yield and yield components of corn, an experiment was carried out during the crop seasons of 2010 and 2011 on Research Farm, Islamic Azad University of Gonabad as a split factorial within randomized complete block design with three replications. The main plots with irrigation factor and four levels were considered: A) full irrigation, B) stopping irrigation at pollination step, and C) stopping irrigation at the seed filling and four levels of zinc sulfate including 0 and 0.5%, 1% and 1.5% spraying (tassel initiation and grain filling) were as the subplots. The drought stress reduced the thousand kernels weight (TKW) in seed filling stage and the number of seeds per ear in tasseling stage about 11% and 27% less than the one of control treatment, respectively. Zinc increased the thousand kernels weight from 27.3 to 31.3 grams and induced an increase in the number of seeds per ear from 710 to 770. The results obtained within the present research showed that zinc spray has fairly improved the effects caused by drought stress.

Key words: Drought stress; Zinc; 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; 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 population increase by about 6 times and the need for more food during the last 100 years, the incidence of this

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

The efficacy of fertilizers will be reduced in low irrigation conditions, especially if the use of these fertilizers is not consistent with the vegetative growth of plants. Among fertilizers, zinc sulfate plays a more important role in stomata regulation and ion balance in plant systems to reduce the tensions of draught. Thus, fertilizer consumption should be balanced and efficient during water shortage and the use of fertilizers such as zinc sulfate should be especially considered (Baybordi, 2006; Babaeian *et al.*, 2010). However, it should be noted that zinc is very low in soils of Iran which are calcareous soils and solubility of this low amount is very little due to drought and salinity, being calcareous, high pH, low organic matters, continuous drought and unbalanced use of fertilizers. Therefore, the plants that grow in such soils are mainly damaged because of zinc deficiency and have the related symptoms (Salehi *et al.*, 2004). One of the most important effects of lack of moisture is that mobility of some elements such as zinc will reduce in the soil solution by decreasing soil moisture and the plant will be more encountered with deficiency of this element given the root growth restrictions (Kafi and Rostami, 2007). It is worth noting that zinc is the essential low energy element for plants, animals and man (Yahyavi Tabriz *et al.*, 2004). More than 300 enzymes involved in metabolic processes of human include

zinc. Although plants' need for zinc is very low, if sufficient quantities of this element are not available, plants will suffer from physiological stress resulting from deficiency of multiple enzyme systems and the other zinc-related metabolic functions (Banks, 2004). Baybordi reported in 2006 that among microelements, the shortage of zinc causes the main problem in production, especially for plants in arid and semiarid soils that have water shortage. Therefore, the proper use of this element in arid and semiarid regions is crucial to improve growth and yield of plants (Jasso de Rodriguez *et al.*, 2002). Accordingly, during experiments on seed yield, Sharafi *et al.* (2002) observed that zinc sulfate spraying had a significant effect on seed yield and ear yield. Given the above mentioned points, it seems necessary to achieve the adequate concentration of zinc sulfate that can reduce the effects of drought stress while meeting the plant needs; because the use of zinc sulfate increases the crop yield, promotes the quality of products and consequently, achieves the enrichment and improvement of the community health (Borrell *et al.*, 2008).

MATERIALS AND METHODS

This study was conducted as a split plot experiment with three repetitions at Research Farm, Islamic Azad University of Gonabad. In this experiment, four levels of irrigation, including A) full irrigation, B) stopping irrigation at pollination step, and C) stopping irrigation at the seed filling were as main

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plots and four levels of zinc sulfate including 0 and 0.5%, 1% and 1.5% spraying (tassel initiation and grain filling) were as the subplots. Each of the experimental plots included four 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 85 thousand plants per hectare 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. Finally, samples from each experimental plot were transported to the laboratory to determine the oil percentage and oil content after the grain harvest, and subsequently, the oil percentage of each sample was determined using the existing methods. 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 zinc spraying on seed yield to be significant ($P < 0.05$) (*Table 1*). The highest seed yield was related to the application of 1% concentration zinc in the stress free conditions with 897 grams per square meter, and its lowest value was related to the lack of application of zinc in stressful conditions on grain filling stage with 765 grams per square meter (*Table 1*). Seed yield increased significantly in all stress treatments through zinc spraying. In the stress treatment at the grain filling stage, the increase was 10%, while there was no change in the full irrigation condition. Zinc sulfate spraying with concentration of 1.5% increased seed yield by 5% compared to lack of spraying. However, no significant difference was observed with concentrations of 0.5% and 1%. Seed yield in stress treatment showed a decrease of 7.8% at the grain filling stage where the greatest reduction in seed yield was related to the different stages of stress. These data suggest that with the occurrence of drought during the reproduction stages, the grain filling period will be reduced, and consequently, the grain weight will be diminished (Flagella *et al.*, 2002). In addition, 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).

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

Treatment	GY (g m ⁻²)	BY (g m ⁻²)	GN	1000GW (g)	RWC (31DAS)	RWC (42DAS)	SPAD 30(DAS)	SPAD (41(DAS)	
Irrigation	I _{CON}	882.0a	1805.7a	777.4a	32.8a	51.2a	66.3a	38.4a	36.2a
	I _{8LEAF}	849.0ab	1747.4b	694.3ab	31.1ab	45.9b	66.4ab	35.2ab	36.1a
	I _{TAS}	823.0b	1484.7ab	564.0bc	28.9bc	47.2b	62.3b	33.3b	32.4b
	I _{SFD}	813.0b	1806.2a	611.0c	26.2c	50.2b	57.6c	34.3b	29.2c
Zn rate	Zn ₀	820.0b	1747.0b	710.5c	27.3b	45.3b	61.3	34.2	31.5
	Zn _{0.5}	838.0ab	1736.3b	750.0b	31.1a	49.2a	62.1	35.1	33.3
	Zn ₁	846.0ab	1827.0ab	762.3ab	31.3a	49.3a	61.8	34.9	33.9
	Zn _{1.5}	862.0a	1833.6a	770.2a	31.2a	49.3a	63.5	35.5	33.8
Significant ¹									
Irrigation	*	*	*	**	*	*	*	**	
Zn rate	*	**	**	**	*	ns	ns	ns	
I×Zn	**	ns	ns	ns	ns	ns	ns	*	

¹Significant effects are denoted as: ns, *, **, non significant or significant at P ≤ 0.05, 0.01, respectively.

I_{CON}: complete irrigation, I_{8LEAF}: stopping irrigation at the 8 leaf stage I_{TAS}: stopping irrigation at the tasseling stage, I_{SFD}: stopping irrigation at grain-filling stage. Zn₀: Without Zn, Zn_{0.5}: With 0.5% Zn, Zn₁: With 1% Zn, Zn_{1.5}: With 1.5% Zn, GY: Grain yield, BY: Biological yield, GN: Number of grain in ear, 1000GW: 1000 grain weight, RWC: Relative water content in 31 and 42 days after sowing, SPAD: Chlorophyll content in 30 and 41 days after sowing.

Yield Components

Irrigation cut off (drought stress) and zinc sulfate spraying influenced significantly the seed weight; however the interaction between drought stress and zinc sulfate spraying did not affected significantly on calculated parameters (*Table 1*). The lowest seed weight (32.8 g) was observed in the non-irrigated treatment in the grain filling stage that was 11% lighter than

seed weight in full irrigation treatment.

The results of many studies show that grain weight can be influenced by irrigation interval (Thalooth *et al.*, 2006). Also, the maximum seed weight was obtained from treatment through spraying with a concentration of 1% (31.3 g). The positive effect of zinc sulfate spraying on seed weight has been also reported by other

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researchers (Baybordi, 2006; Banks, 2004).

The effect of irrigation cut off (drought stress) and zinc sulfate spraying on the number of seeds per ear was significant, whereas the interaction between drought stress and zinc sulfate spraying was not significant (*Table 1*). The lowest number of seeds per ear was given in drought treatment in tassel initiation, which was 27% less than control treatment. 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. These results are consistent with the results obtained by Goksoy *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).

Zinc sulfate spraying had also a significant impact on the increase of the number of seeds per ear, in a way that spraying with a concentration of 1.5% increased the number of seeds per ear by about 8.5% (*Table 1*). The results of experiments by Agele *et al.* (2007) also indicate the positive effect of micronutrient fertilizers such as zinc sulfate on the number of seeds regarding the sunflower. Moreover, some reports have been presented on the positive role of the use of zinc sulfate fertilizer on the number of seeds generated in the shrub of wheat, canola and sunflower.

Biological Yield

The effect of water shortage and zinc sulfate spraying 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 8-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 zinc sulfate spraying showed that biological yield was raised with increase of zinc sulfate spraying (*Table 1*). Considering that the effect of drought stress and zinc sulfate spraying on biological yield was not significant, but the mean comparison results showed that spraying treatment with 1% concentration 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 spraying were not significant.

Plant Relative Water Content (RWC)

Effects of drought stress as well as zinc sulfate spraying on relative water content became significant 31 and 42 days after planting ($P < 0.05$), while the interaction of drought stress and zinc sulfate spraying 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 full irrigation (51.17%) and its lowest value was obtained in drought stress treatment in the 8-leaf stage (45.93%) which was in the same statistical group with drought stress treatment in tassel initiation period. The highest plant relative water content (42 days after planting) was obtained in drought stress treatment in the 8-leaf stage which was in the same statistical group as full irrigation 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. 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).

Mean comparison results in zinc sulfate spraying also showed that the highest relative content was obtained in the spraying with concentration of 1.5 (49.28%) (*Table 1*), which increased 7% compared with no-spraying treatment. Comparison results of mean of interactions between drought and zinc sulfate spraying suggested that at the level of full irrigation (control), spraying 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 zinc sulfate 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 zinc sulfate spraying (*Table 1*).

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Chlorophyll index

The effect of drought stress on chlorophyll index was significant ($P < 0.05$) (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 zinc sulfate spraying and the interaction between drought stress and zinc sulfate spraying was not significant (*Table 1*). Reviewing mean comparisons showed that in drought stress levels, the highest chlorophyll index was obtained in full irrigation treatment (38.3%) and the lowest chlorophyll index was obtained in non-irrigated treatment in tassel initiation period (33.3%). The effect of drought stress and the interaction between drought stress and zinc sulfate spraying on the chlorophyll index was significant (41 days after planting), but the effect of zinc sulfate spraying was not significant (*Table 1*).

Mean comparison investigation showed that chlorophyll index was also decreased with increase of drought stress at this stage of measurement, in a way that the maximum chlorophyll index was obtained in full irrigation treatment (36.15%) and its lowest value was obtained in non-irrigated treatment at grain filling stage (29.2%) (*Table 1*). According to the mean comparison results, chlorophyll index increased with zinc sulfate spraying, although it was not statistically significant. The highest amount of chlorophyll index

was obtained in the spraying of 1% concentration (*Table 1*).

The mutual effects of drought stress and zinc spraying were also significant. Its maximum value was obtained in full irrigation condition with no spraying (41%) (*Table 1*). Results show that maximum chlorophyll index was obtained in spraying with concentration of 1% in all three phases of drought stress. Side effects of stress were decreased with increase of spraying. Survey results showed that drought stress in the 8-leaf stage (first measurement) reduced chlorophyll index by 13% and showed a 24% reduction in reproductive stage (second measurement). 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 zinc element 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, zinc spray decreases the effect of number of grains on the grain yield ($R^2 = 0.06$) (*Figure 1*). Grain's weight importance is increased. As a result, if zinc spray is used, grain's weight importance will be increased as compared with the number of grains in determining the grain yield (*Figure 2*).

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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. According to 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, irrigation cut off in the reproductive stage had the greatest negative influence on *Zea mays* yield. The results showed that the irrigation cut off in the 8-leaf stage reduced the yield only by 8%, while it reduced the yield by 20% in the reproductive stage. Thus, when the plant faces water shortage, the proper selection of the time of low irrigation application is considered the right tool for optimal planning in the use of water.

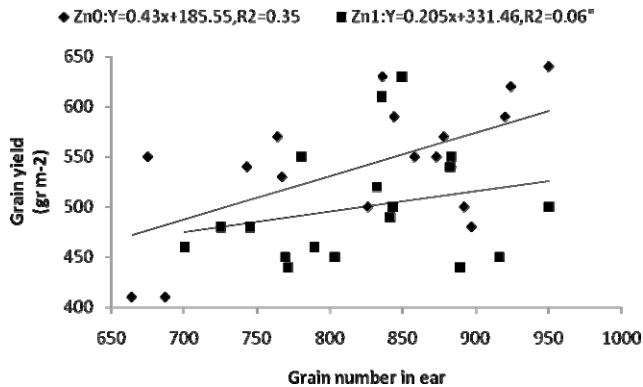


Figure 1 - Effect of zinc on the relationship between grain yield and grain number in ear of corn

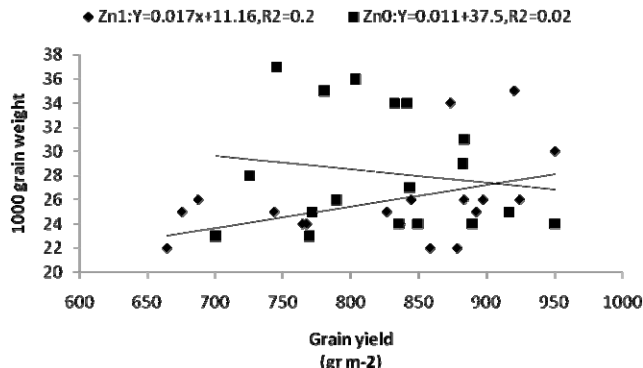


Figure 2 - Effect of zinc on the relationship between grain yield and 1000 grain weight in corn

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Reduction of chlorophyll index and plant relative water content also reduced seed yield. In addition, the results showed that application of zinc sulfate reduced the side effects of stress. Overall, the results of this study showed that the use of zinc spraying 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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