

EFFECTS OF NITROGEN AND ZINC SPRAY 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, nitrogen 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 Emam Khomeyni research Farm in Mahvellat as a split factorial within randomized complete block design with three replicates. The main plots with irrigation factor and three levels were considered: full irrigation, stopping irrigation at anthesis step and stopping irrigation at the seed filling stage. Subplots were considered with and without nitrogen and zinc spray. The drought stress reduced the grain yield in anthesis stage more than other stages. Drought stress effects significantly on stem and ear diameter, ear length, chlorophyll value, leaf area index, 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. Nitrogen increased the seed yield and yield component except thousand grains weight and the number of row in ear. Using Zn, as compared with control treatment, causes the increase of grain yield, thousand grains weight and number grain in ear 16.5, 9 and

5.5%, respectively. The results obtained from the present research showed that anthesis stage was most sensitive stage to drought stress. Also nitrogen and Zn could somewhat reduce the impact drought stress on corn.

Key words: Drought stress; Nitrogen; Zinc; Spray; Corn.

INTRODUCTION

Drought is one of the factors, which threatens the agricultural products in most parts of the world (Abolhasani and Saeidi, 2004). Drought causes stress in plants. Not only it is resulted from precipitation reduction and hot temperatures, but also when the soil is moist, for some reasons such as high salinity of soil and/or soil frost, the moisture cannot be used by the plant and it causes stress in the plant (Baybordi, 2006 ; Soriano *et al.*, 2004). Drought and water shortage are considered as objective realities in Iran. In the past, water crisis has not been so serious as

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today; however, by increasing population during the past 100 years and becoming approximately six times bigger, the incidence of this crisis is more evident than before (Castro *et al.*, 2006; Goksoy *et al.*, 2004).

Under water shortage conditions, the effectiveness of fertilizers decreases, especially if consumption of these fertilizers is not compatible with the vegetative growth of plants. Among fertilizers, zinc sulfate fertilizer plays a more important role in adjusting stomata and ionic balance in plant system to decrease stresses caused by water shortage; therefore, under water shortage conditions, consumption of fertilizers should be balanced and optimized and special attentions should be taken to the consumption of zinc sulfate fertilizers (Karam *et al.*, 2007; Babaeian *et al.*, 2010). 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 zinc contents are too low. Therefore, the plants which grow in such soils are mainly suffered from shortage of iron and zinc and shortage indications are observed in them (Jaleel *et al.*, 2009).

Nitrogen and water are two of the most important factors for crop production. The production of maize responds positively (Liua and Zhang, 2007) to an increase in the amount of

water and nitrogen applied until the optimum level has been reached. However, for many farming systems there are concerns with respect to the availability of resources, including water, as well as the impact of farming practices on the environment, such as nitrate leaching due to excessive applications of nitrogen (N). Drought stress reduces the leaf area (Pandey *et al.*, 2000), plant height (Soler *et al.*, 2007), shoot growth (Stone *et al.*, 2001), and grain yield (Payero *et al.*, 2006), while crop N demand and N uptake are a function of both root and shoot growth (Grindlay, 1997). Therefore, optimizing the amount of N based on the amount of available water is needed to improve maize production at both the local and regional level.

The yield components of tropical maize varieties differ considerably (Feil *et al.*, 1992). Yield components can be modified to some extent by crop management and environmental factors. Balko and Russell (1980) found that N fertilization had varying effects on the ear number per plant, ear length, and kernel weight of inbred lines. Compared with small grain cereals, the kernel weight of maize is relatively flexible; artificially reduced seed set caused increases in kernel weight from 0 to 25%, depending on the genotype (Kiniry *et al.*, 1990). It is assumed that prolific and semi-prolific maize varieties adjust better to environmental stresses and have greater stability of performance across environments (Thomison and Jordan, 1995). The

EFFECTS OF NITROGEN AND ZINC ON YIELD OF CORN IN DROUGHT STRESS

harvest index (HI; proportion of grain dry matter to total shoot dry matter) of temperate maize is often above 0.5 (Costa *et al.*, 2002; Earl and Davis, 2003). Much lower values have been reported for tropical lowland maize (Feil *et al.*, 1992). The HI can be very low on soils with decreasing water supply (Bolaños and Edmeades, 1993). On the other hand, a HI of more than 0.5 has been reported for tropical maize grown at medium altitudes. Thus, the HI of tropical maize varies considerably and seems to depend on variety, crop management, growing season, and other factors (Hay and Gilbert, 2001). While the effects of irrigation and N application on the grain yield, yield components, and HI of maize have been reported in numerous papers, relatively little has been published about the interactive effects of these factors. As a rule, research has focused on the response of maize to water shortage around silking or later, whereas the effects of water deficit before anthesis have received relatively little attention.

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

MATERIALS 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 Emam Khomeyni research field of Mahvellat (34°40' N 58°25' E and height of 985 m). The soil

of experimental plot was silt, pH 7.71, EC 1.92 dSm⁻¹, organic carbon 0.2%, available nitrogen 0.02%, phosphorus 0.6% and potassium 0.2%. Experiment treatments including drought stress were carried out at three levels of full irrigation, stopping irrigation at anthesis stage and stopping irrigation at the seed filling stage. Subplots were considered with and without nitrogen and zinc spray.

Generally, there were 36 subsidiary plots with the surface area of 20 m² (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, 150 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 N and ZN rates, the grain yield of drought-stressed maize was 32% lower than that of well-watered maize (*Table 1*). The grain yield reductions are well within the range of yield decreases due to pre-anthesis water deficit (Abrecht and Carberry, 1993).

The significant water regime \times N 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, N supply resulted in maximum grain yield under full irrigation, whereas without N resulted in minimum grain

yield under pre-anthesis drought (*Table 1*).

The results of analyzing data variance showed the interaction between drought stress and zinc spraying on seed yield to be significant ($P < 0.01$) (*Table 1*). The highest seed yield was related to the application of zinc in the full irrigation conditions with 1114.95 g m^{-2} , and its lowest value was related to the lack of application of zinc in pre-anthesis drought with 491.2 g m^{-2} (*Table 1*).

Both supply N and Zn increased the grain yield significantly about 16.5 and 21.6%, respectively, more than control (*Table 1*). But, in pre-anthesis and pre-seed formation stages, both supply N and Zn increased the grain yield slightly that was more in pre-seed formation stage (*Fig. 1*).

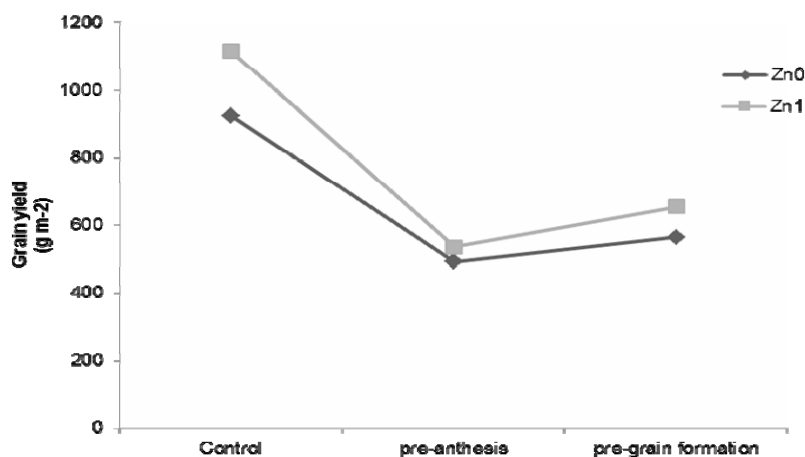


Figure 1- Effect N (top) and Zn (bottom) on grain yield under drought stress

EFFECTS OF NITROGEN AND ZINC ON YIELD OF CORN IN DROUGHT STRESS

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 (g)	1000 GW	GNR	RNE	UG (%)	RWC (%)	SPAD (%)
Irrigation									
I _{CON}	1018.99a	1692.17a	332.93a	290.50a	24.12a	13.79a	29.31c	89.23a	50.02a
I _{TAS}	512.66c	1312.41c	198.97c	258.75b	15.97c	12.46b	52.88a	73.48c	43.66b
I _{SFD}	608.06b	1358.58b	255.57b	222.91c	18.44b	13.85a	42.47b	84.17b	44.67b
N rate									
N ₀	643.694b	1408.40b	249.48b	242.50b	18.71b	13.27b	43.41a	80.72b	43.64b
N ₁	782.782a	1500.38a	275.50a	272.27a	20.30a	13.47a	39.70b	83.86a	48.59a
Zn rate									
Zn ₀	658.974b	1416.92b	255.85b	246.00b	19.40a	13.11b	43.49a	81.59b	44.73b
Zn ₁	767.503a	1491.86a	269.14a	268.77a	19.61a	13.62a	39.61b	83.00a	47.50a
Significant¹									
Irrigation	**	**	**	**	**	**	**	**	**
N	**	**	**	**	**	*	**	**	**
Zn	**	**	**	**	ns	**	**	****	**
I×N	**	**	**	ns	**	ns	**	ns	ns
I×Zn	**	**	**	ns	*	**	**	**	ns
N×Zn	*	*	ns	ns	ns	ns	ns	ns	ns
I×N×Zn	**	**	**	ns	*	ns	ns	ns	ns

¹Significant effects are denoted as: ns, *, **, non significant or significant at P ≤ 0.05, 0.01, 0.001, respectively; I_{CON}: complete irrigation; I_{TAS}: stopping irrigation at the tasseling stage; I_{SFD}: stopping irrigation at grain-filling stage; Zn₀: without Zn; Zn₁: with Zn; N₀: without N; N₁: with N; 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.

Yield components

Both drought and without N supply reduced the number of grains per ear, number of row per ear, number of grains per row, weight of thousand grains and biological yield. The grain number in row and ear and biological yield were significantly affected by the water regime \times N rate interaction (*Table 1*). Under drought, N supply increased number of grains per ear and biological yield about 4.3 and 7%, respectively, than control (*Table 1*). In contrast, the number of grains per ear increased with N application regardless of the water regime, and the differences between the supply and without supply N treatments were generally small and significant (*Table 1*). Under drought, Zn supply was similar N supply and weight of thousand grains no significantly affected by N and Zn supply (*Table 1*), but under full irrigation, all of yield components were significantly affected by N and Zn supply except number of grains per row that not affected Zn supply (*Table 1*). The 1000 grain weight of drought stressed plants was considerably lower than that of well-watered plants; the average reductions due to drought were 17% (*Table 1*). Thus, both pre-anthesis and pre-grain formation a decrease in 1000 grain weight and, to a lesser extent, a decrease in number of grains per ear contributed to lower grain yields due to water shortage. In studies with US maize, it was also found that grain number was the yield component most affected by pre-anthesis water

deficit (Lorens *et al.*, 1987). The effects of drought on 1000 grain weight were more distinct in our study than in that of Weerathaworn *et al.* (1992), which was also conducted on Farm Suwan in the dry season. NeSmith and Ritchie (1992) observed variable effects of drought on the 1000-grain weight. They assumed that one source of variability of findings may be that very small grains were discarded in some studies but not in others. There were few very small grains in our study, and they were retained in harvesting. Eck (1986) reported that the adverse effect of pre-anthesis drought on the grain number was compensated for by an increase in 1000 grain weight. Low 1000 grain weight due to drought stress, as found in our experiments, may indicate that the plants were unable to fully meet the demand of the growing grain. Since the long-term consequences of pre-anthesis drought include a smaller number of leaves, a smaller leaf area, and shorter internodes (NeSmith and Ritchie, 1992; Abrecht and Carberry, 1993; Siri, 1993), early drought stress probably reduced the capacity of assimilate production and/or storage during grain filling. However, pre-anthesis drought may also have affected the grain size in a different way. The capacity of maize grains to store assimilates is a function of the number of endosperm cells and starch granules established during the first 10–14 days after pollination (Commuri and Jones, 2001). Thus, reduced assimilate production due to a small green leaf area, reduced

EFFECTS OF NITROGEN AND ZINC ON YIELD OF CORN IN DROUGHT STRESS

capacity to store assimilates due to short internodes, or high levels of endogenous abscisic acid (Mambelli and Setter, 1998) during the above-mentioned critical period may have limited the 1000 grain weight in our study.

Harvest index (HI)

The average HI of well-watered maize ranged from 0.54 to 0.65 (*Table 1*). In the present study, the lowest mean HI of continuously irrigated maize was found in without N and Zn supply when the total dry matter was higher and the grain yield lower than control, whereas, the plants were more moist, and therefore, less brittle at the harvest. Thus, differences in the extent of leaf shedding and in the loss of leaf material during collection and processing may have contributed to the variation in the total biomass and HI. The grain number was average well-watered maize without N and Zn supply (*Table 1*), while the 1000 grain weight was low, irrespective of the water regime (*Table 1*). This suggests that insufficient assimilate supply during grain filling limited kernel size. On the other hand, the total biomass production in the well-watered environment was high. Thus, the allocation of assimilate to the growing grains may have been inefficient in well-watered maize without N and Zn supply. It is also possible, however, that unfavorable conditions during the establishment of the number of endosperm cells and starch granules limited the kernel size.

Water deficit before tasseling decreased the HI more than water deficit before grain formation (*Table 1*). Similar drought effects on the HI have been reported for temperate (Lorens *et al.*, 1987) and tropical (Siri, 1993) maize. The HI was highest (0.46) for Water deficit before grain formation with N and Zn supply.

Relative water content (RWC)

RWC and chlorophyll content were significantly affected by drought stress; N and Zn supply (*Table 1*). Under pre-anthesis and pre-seed formation drought stress, RWC was decreased significantly about 21 and 5.6%, respectively, less than control (*Table 1*). 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.*, 2007). Mean comparison results in N and Zn spraying also showed that the highest relative content was obtained in the spraying of N and Zn (83%) (*Table 1*), which increased 4% compared with no-spraying treatment.

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 full irrigation treatment (50%) and the lowest chlorophyll index was obtained in pre-anthesis drought stress (43.6%). According to the mean comparison results, chlorophyll index increased significantly with N and Zn spraying about 11.6 and 6.8%, respectively (*Table 1*). The highest amount of chlorophyll index was obtained in the spraying of N with 48.6% (*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).

CONCLUSIONS

Maize on moist soils requires more N and Zn to achieve the maximum grain yield than drought stressed maize. Pre-anthesis water deficit affects the grain set and, to a lesser extent, the mean grain weight. The latter suggests that the grain size is limited by an inadequate assimilate supply to the growing grain.

Overall, the results of this experiment showed that corn 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 corn yield.

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EFFECTS OF NITROGEN AND ZINC ON YIELD OF CORN IN DROUGHT STRESS

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