

**STUDY ON FOLIAR APPLICATION OF MN AND ZN NUTRIENTS ON YIELD AND
YIELD COMPONENTS OF MAIZE (*ZEA MAYS L.*) UNDER DROUGHT STRESS
CONDITION**

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ABSTRACT

This study was laid out to determine the effects of irrigation period and foliar application of Zn and Mn nutrients on yield and yield components of maize (SC600 hybrid), in Islamic Azad University of Boroujerd, Iran, during the growing seasons 2013- 2014. The experiment was laid out in a split-plot arrangement based on randomized block design with three replications. Treatments were different irrigation periods (7, 14 and 21 days) in main plots and foliar application of Mn and Zn in three levels of (Zn+Mn with 5 in 1000 concentration, Zn with 5 in 1000 concentration and Mn with 5 in 1000 concentration) with control treatment in sub plots. The results of present study revealed that the effects of Irrigation period and application of Zn and Mn nutrients on all traits were significant. Also, the interaction effect of Irrigation period and application of Zn and Mn nutrients was significant on plant height, 100grain weight and grain yield only. The comparison of the mean values for irrigation period showed that 7 day irrigation period treatments had the highest number of row per cob, number of grain per cob, biomass yield and harvest index and 21 day irrigation period treatment had the lowest of them. In foliar application of Zn and Mn nutrients combined application of Zn and Mn treatment had the highest number of row per cob, number of grain per cob, biomass yield and harvest index and control treatment had the lowest and the

differences were significant. The comparison of the mean values showed that combined application of Zn and Mn nutrients in 7 day irrigation period had the highest plant height, 100 grain weight and grain yield and non application of nutrient treatment in 21 day irrigation period treatment had the lowest of them and differences were significant. However, the present study concluded that maximum production of yield and its components of maize was recorded for 7 days irrigation period and combined application of Mn and Zn fertilizers. Therefore, we can increase yield and yield components of maize by decrease of irrigation period and foliar application of Zn and Mn fertilizers specially combined application of them

Key words: Drought, Maize, Mn and Zn

INTRODUCTION

Drought stress is the most important abiotic stress in soybean production in many parts of Iran. Drought stress is a major factor affecting crop yield and yield components and symbiosis (Tajima et al., 2004). Drought stress causes deceleration of cell enlargement and thus reduces stem length by inhibiting inter nodal elongation and also checks the tillering capacity of plants (Ashraf and O'Leary, 1996). Partitioning and translocation of assimilates is dependent to water availability in soil (Whan et al., 1991). However, Water deficit at early of flowering and pod set increased flower and floret abortion (Osborne et al., 2002) and at seed filling period reduced seed weight (Vieira et al., 1992). Several studies have also shown that optimum yield can be obtained with irrigation at branching, flowering and pod formation stages (Prihar and Sandhu, 1968). In addition, drought stress increasing leaf senescence and indeed reduces source size in

plant (De Souza et al., 1997). Drought stress may cause some problems in absorbing process or the process of nutrient accumulation, this can not only lead to fertilizer loss but also causes decrease in yield of grain and plants (Chogan et al, 2004). Biglouei et al (2007) reported that the increase of drought stress in K.S.C.704 corn, led to increase of grain yield and protein percentage. They also declared that grain protein in irrigation treatments after 50, 75 and 100 percent water depletion, were relatively 5.8, 7.2 and 7.4. The studies of researchers have indicated that, lack of organic materials and existence of alkali reaction in calcareous soils can lead to lack of micronutrients in these soils (Auge, 2001). Several mechanisms have been reported to be involved in the physiological response, carbon (C) shortage and nodule C metabolism, oxygen limitation, and feedback regulation by the accumulation of N fixation products, which

results in poor nodulation and reduced amounts of fixed N (Zahran, 1999). However, Serraj and Sinclair (1998) founded that a large variation in sensitivity to water deficit, among soybean cultivars, can be related to nodule formation and growth, and soybean genotypes can be selected for N₂ fixation and tolerance to water deficits. Water stress can decrease number and shape of root hairs (Worral & Roughley, 1976), nitrogenase activity and syntheses of: sucrose, glutamate and glutamine (Ramos et al., 1999) that laid to the reduce of photosynthetic accumulation and plant height. Zinc plays an important role as a metal component of enzymes (alcohol dehydrogenase, superoxide dismutase, carbonic anhydrase and RNA polymerase) or as a functional, structural, or regulator cofactor of a large number of enzymes (Marschner, 1986). Mahady (1990) found that foliar application of Zn SO for faba bean plants increased number of pods/plant and seed yield/fed. Zinc and Mn are considered to be two of the smallest nutritious elements for many organisms. Grewal et al. (1997) reported increased wheat production with application of zinc and boron over control. Grain protein content and baking quality highly depend on genetic background and environmental factors,

especially influence of drought and heat stress, during the grain filling period (Ottman et al., 2000). Nearly 200 enzymes and transcription elements of zinc need it as one of the most essential components. Zinc plays an important role in protein and carbohydrates syntheses. It also has effects on growth of stem and root (Kabata-Pendias, 1999). Soleimani (2006) reported marked increase in number of grains spike-1 of wheat for foliar application of boron and zinc, respectively. Also, Soleimani (2006) reported increase in biological yield for foliar application of zinc.

Therefore this study was planned to examine effect of Mn and Zn fertilizers on yield and yield components of maize under drought stress.

MATERIALS AND METHODS

This experiment was laid out in order to evaluate the effects of foliar application of Mn and Zn nutrients on yield and yield components of maize (SC600 hybrid) under drought stress condition in the faculty of agronomy and plant breeding, Islamic Azad University, Boroujerd Branch (experiment station: Hamedan), Iran during the growing seasons 2013- 2014. Soil property of experimental field showed in table1.

Table 1: Soil property of experiment site

soil Texture	sand (%)	Silt (%)	Clay (%)	K (mg/kg)	P (ppm)	N (%)	pH	EC (ds/m)	Zn (ppm)	Depth
LC	20	45	35	220	8.2	0.1	7.7	0.409	0.88	0-30

The experiment was laid out in a split-plot arrangement based on randomized block design with three replications. Treatments were different irrigation periods (7, 14 and 21 days) in main plots and foliar application of Mn and Zn in three levels of (Zn+Mn with 5 in 1000 concentration, Zn with 5 in 1000 concentration and Mn with 5 in 1000 concentration) with control treatment in sub plots. Foliar use of treatment was applied in early times of morning.

In this field experiment there were 6 rows in each plots and rows were 6 m long with 0.75 m row spacing and plant to plant spacing was 18 cm too. At maturity, two outer rows for each plot, 50 cm from each end of the plots, were left as borders and the middle 3m² of the four central rows were harvested. Then yield components were calculated as standard methods with using 8 plant. To determine grain yield and biomass yield, we removed and cleaned all the seeds produced within middle 3m² of the four central rows in each plot. Then grain yield and biomass yield

recorded on a dry weight basis. Yield was defined in terms of grams per square meter and quintals per hectare. Replicated samples of clean seed (broken grain and foreign material removed) were sampled randomly and 1000-grain were counted and weighed. The harvest index was accounted with follow:

$$HI = (\text{Economical yield} / \text{Biological yield})$$

Then, statistical analyses to determine the individual and interactive effects of different irrigation periods and foliar application of Zn and Fe were conducted using JMP 5.0.1.2 (SAS Institute Inc., 2002). Statistical significance was declared at $P \leq 0.05$ and $P \leq 0.01$. Treatment effects from the two runs of experiments followed a similar trend, and thus the data from the two independent runs were combined in the analysis.

RESULTS AND DISCUSSION

Plant height: results of analysis of variance showed that, the effect of irrigation period and foliar application of Zn and Mn and interaction between them on plant height

were significant (table 2). The comparison of the mean values of the plant height showed that application of all nutrient treatment in 7 day irrigation period had the highest (215cm) plant height and non application of nutrient

treatment in 21 day irrigation period treatment had the lowest (161cm) plant height (fig 1) and differences were significant.

Table 2: Analysis of variance (mean squares) for yield, yield components of maize under water stress and foliar application of Zn and Mn

treatments	df	Plant height	number of row per cob	number of grain per cob	100 grain weight	biomass yield	grain yield	harvest index
R	2	52.9	1.9	3958	3.5	1.2	4.09	118.4
Irrigation (A)	2	6033**	34.9**	151177**	324**	291.7**	128.3**	1035**
Ea	4	37.02	0.55	531	5.45	1.11	3.11	199
Foliar application of Zn and Mn (B)	3	849**	17.22**	15140**	47.7**	65.5**	26.7**	205**
A*B	6	258.3**	2.15	1236	5.13*	0.52	2.07**	61.2
Eb	18	91.6	1.71	547	1.73	1.17	0.49	25.8
CV(%)		4.8	9.9	5.4	6.8	7.16	12.07	14

ns: Non-significant, * and **: Significant at 5% and 1% probability levels, respectively

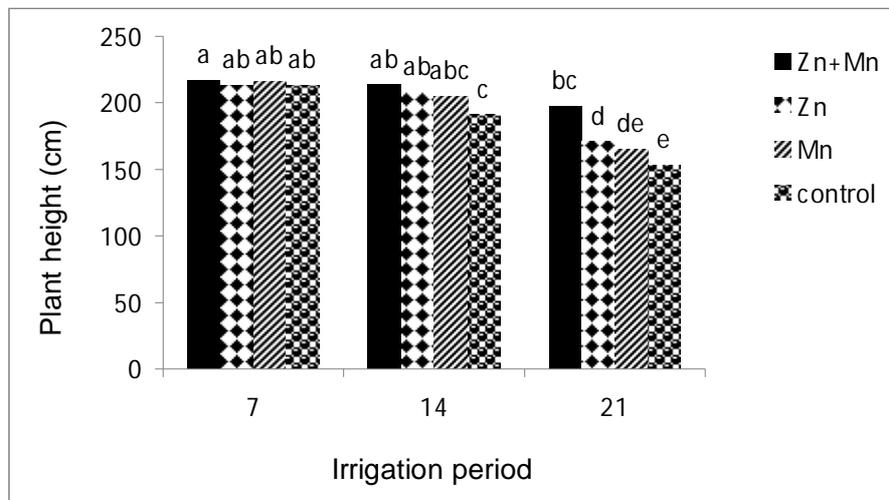


Figure 1: Effect of different irrigation period and foliar application of Zn and Mn on plant height in maize Means by the uncommon letter in each column are significantly different (p<0.05)

Number of row per cob: The analysis of variance showed that the effect of irrigation period and foliar application of Zn and Mn nutrient on number of row per cob was significant (table 2). The comparison of the

mean values of the number of row per cob for irrigation period showed that 7 day irrigation period treatments had the highest (15.5) number of row per cob and 21 day irrigation period treatment had the lowest

(12.2) number of row per cob (fig 2). In foliar application of Zn and Mn nutrients combined application of Zn and Mn treatment had the highest (15) number of row

per cob and control treatment had the lowest (11.5) number of row per cob and the differences were significant (fig 3).

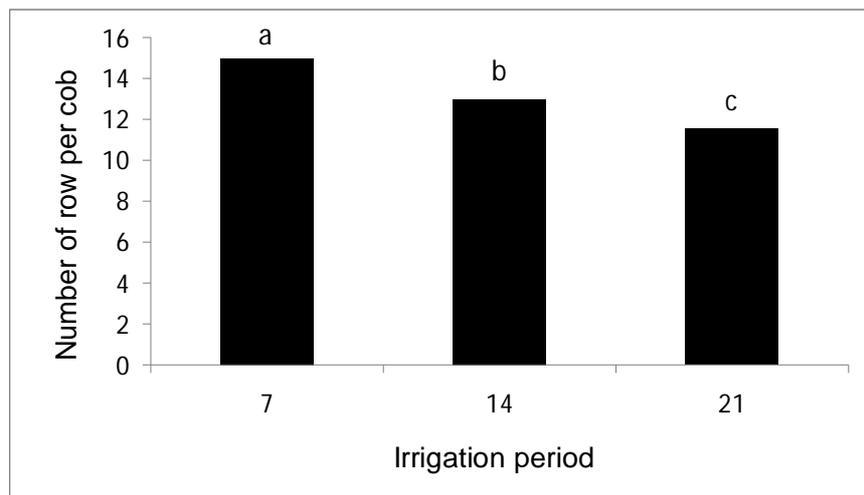


Figure 2: Effect of different irrigation period on number of row per cob in maize. Means by the uncommon letter in each column are significantly different ($p < 0.05$)

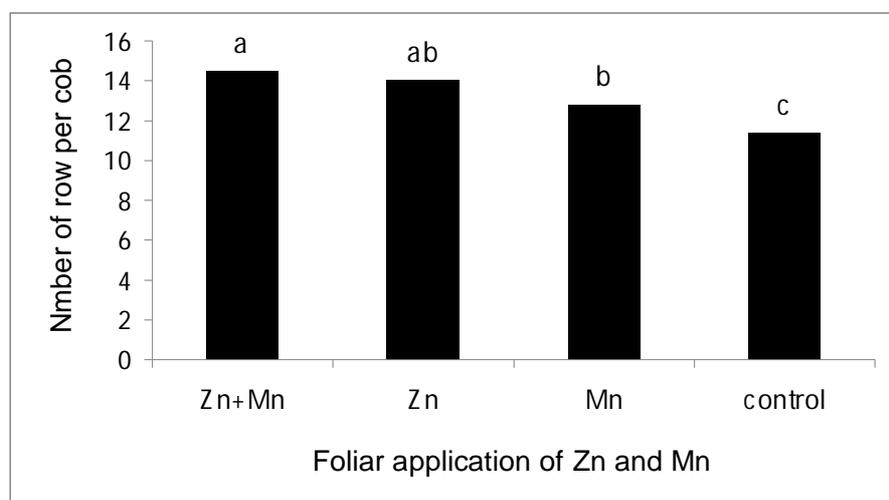


Figure 3: Effect of foliar application of Zn and Mn on number of row per cob in maize. Means by the uncommon letter in each column are significantly different ($p < 0.05$)

Number of grain per cob: The effect of irrigation period and application of Zn and Mn nutrient on number of grain per cob was significant (table 2). The comparison of the

mean values of the number of grain per cob for irrigation period showed that 7 day irrigation period treatment had the highest (540) number of grain per cob and 21 day

irrigation period treatment had the lowest (350) number of grain per cob (fig 4). In foliar application of Zn and Mn treatments combined application of Zn and Mn

treatment had the highest (488) number of grain per cob and control treatment had the lowest (406) number of grain per cob (fig 5).

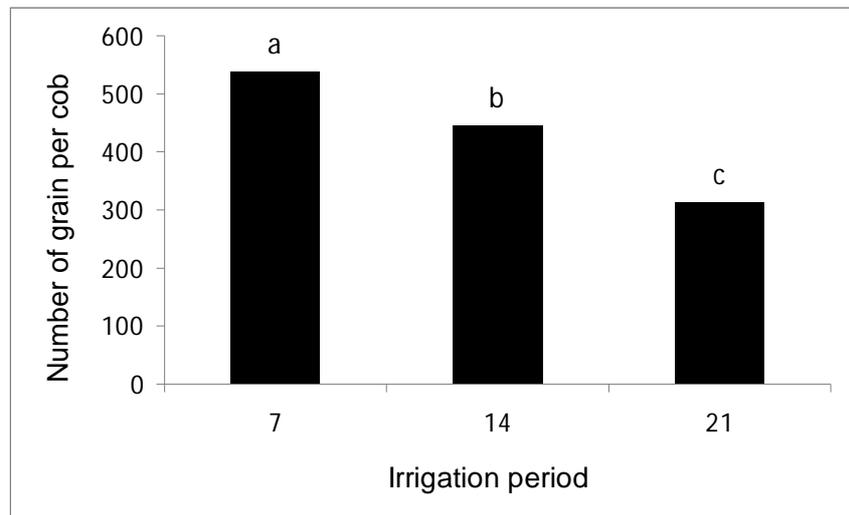


Figure 4: Effect of different irrigation period on number of grain per cob in maize. Means by the uncommon letter in each column are significantly different ($p < 0.05$)

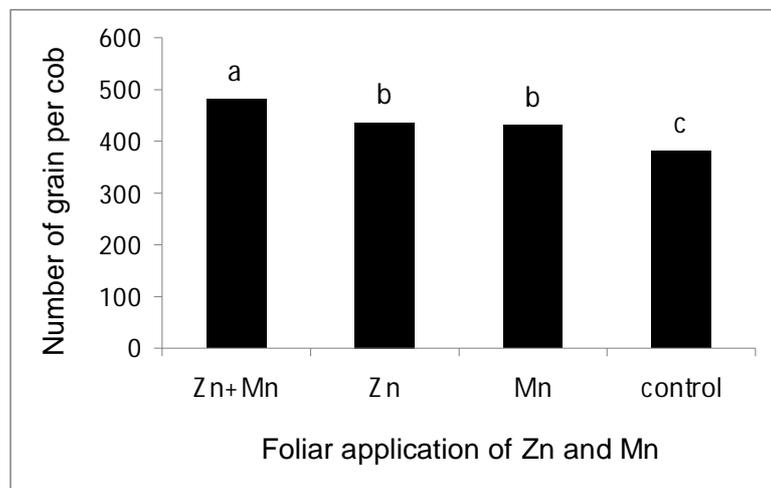


Figure 5: Effect of foliar application of Zn and Mn on number of grain per cob in maize. Means by the uncommon letter in each column are significantly different ($p < 0.05$)

100 grain weight: The results showed that the effect of irrigation period, application of Zn and Mn nutrient and interaction between them on 100-grain weight were significant

(table 2). The comparison of the mean values of the 100-grain weight for interaction between irrigation period and application of Zn and Mn nutrient showed that combined

application of Zn+Mn treatment in 7 day irrigation period treatment had the highest (26.5g) 100-grain weight and non application of any of Zn and Fe in 21 day irrigation period treatment had the lowest (15.5g) 100-grain weight (figure 6).

Biomass yield: The effect of irrigation period and application of Zn and Mn nutrient on biomass yield was significant (table 2). The comparison of the mean values of the

biomass for irrigation period showed that 7 day irrigation period treatment had the highest (20.4 ton/ha) biomass yield and 21 day irrigation period treatment had the lowest (11 ton/ha) biomass yield (fig 7).

In foliar application of Zn and Mn treatments combined application of Zn and Mn treatment had the highest (17.7 ton/ha) biomass yield and control treatment had the lowest (12.2 ton/ha) biomass yield (fig 8).

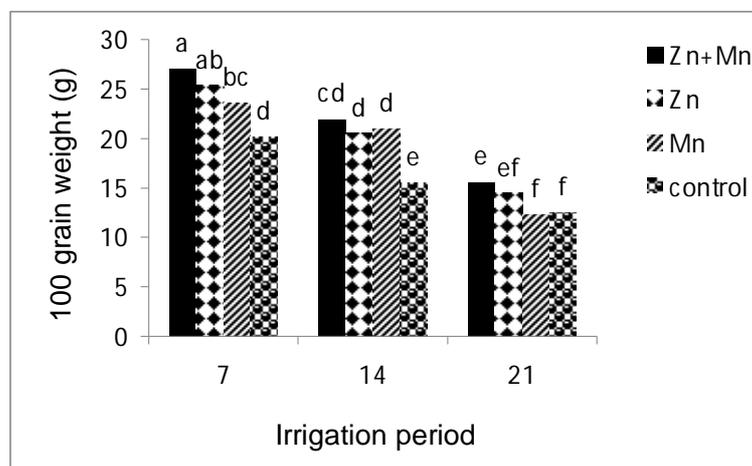


Figure 6: Effect of irrigation period and foliar application of Zn and Mn on 100 grain weight in maize Means by the uncommon letter in each column are significantly different ($p < 0.05$)

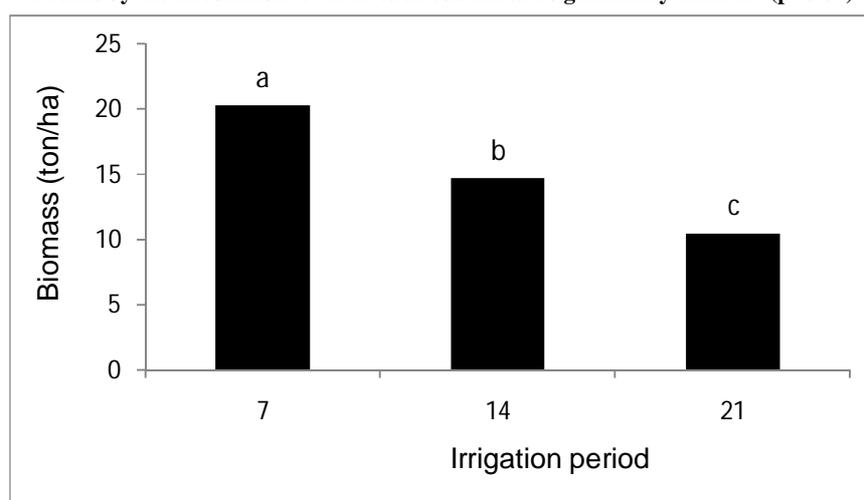


Figure 7: Effect of irrigation period on biomass yield in maize; Means by the uncommon letter in each column are significantly different ($p < 0.05$)

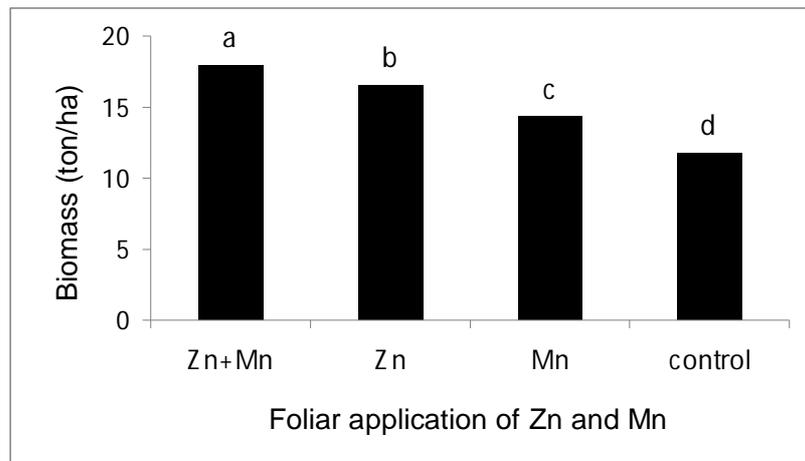


Figure 8: Effect of foliar application of Zn and Mn on biomass yield in maize. Means by the uncommon letter in each column are significantly different ($p < 0.05$)

Grain yield: The results showed that the effect of irrigation period, application of Zn and Mn nutrients and interaction between them on grain yield were significant (table 2). The comparison of the mean values of the grain yield for interaction between irrigation period and application of Zn and Fe nutrient

showed that application of Zn+Mn treatment in 7 day irrigation period treatment had the highest (12 ton/ha) grain yield and non application of any of Zn and Fe in 21 day irrigation period treatment had the lowest (2.2 ton/ha) grain yield (fig 9).

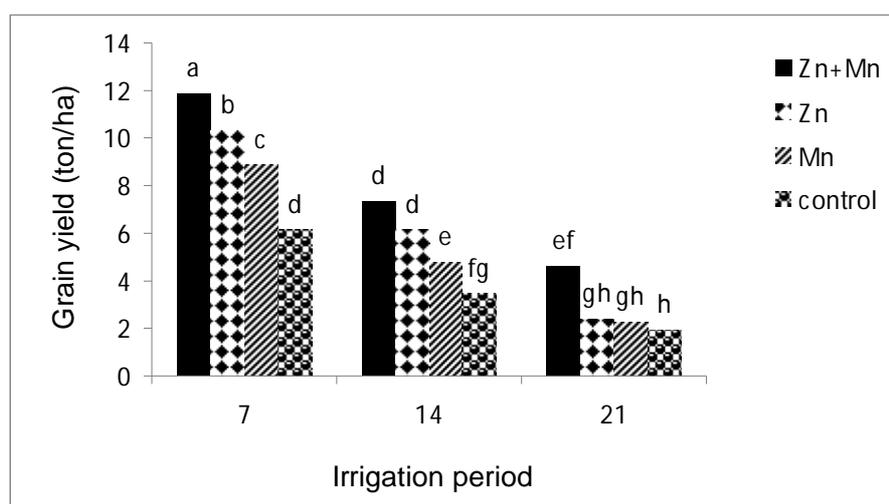


Figure 9: Effect of irrigation period and foliar application of Zn and Fe on grain yield in maize. Means by the uncommon letter in each column are significantly different ($p < 0.05$)

Harvest index (HI): The effect of irrigation period and application of Zn and Mn nutrient on harvest index were significant (table 2). The comparison of the mean values of the harvest index for irrigation period showed that 7 day irrigation period treatment had the highest (45%) harvest index and 21 day

irrigation period treatment had the lowest (26%) harvest index (fig 10). In foliar application of Zn and Mn treatments combined application of Zn and Mn treatment had the highest (42%) harvest index and control treatment had the lowest (31%) harvest index (fig 9).

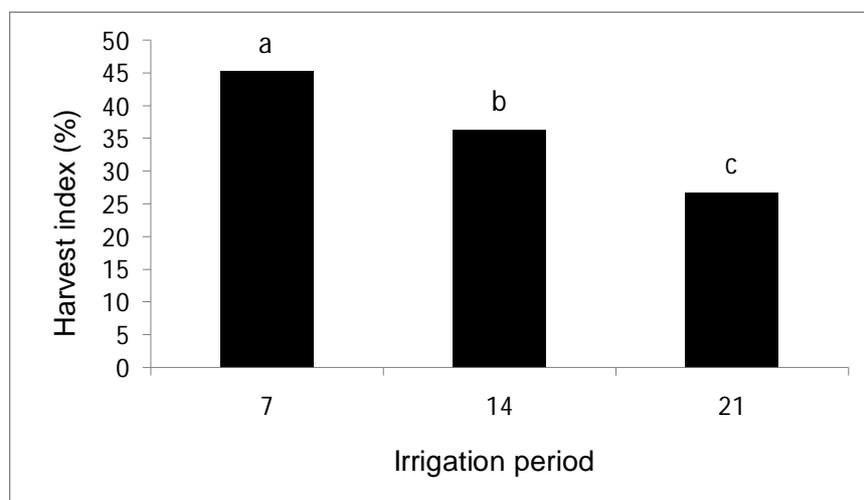


Figure 10: Effect of irrigation period on HI in maize.
Means by the uncommon letter in each column are significantly different ($p < 0.05$)

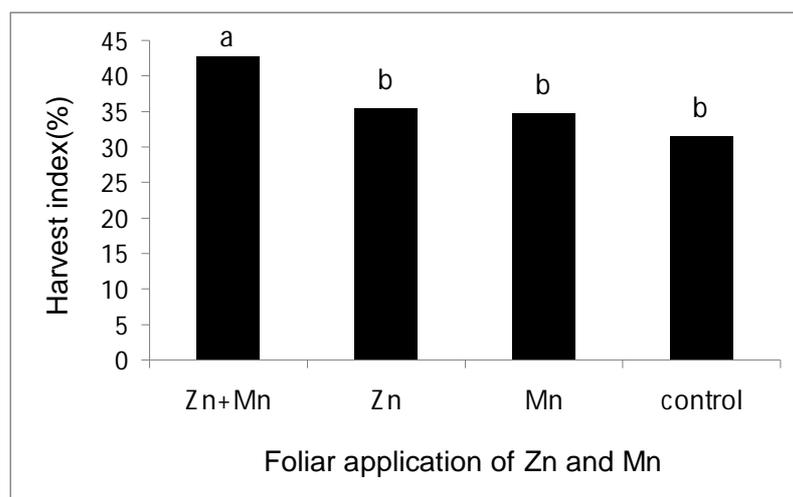


Figure 11: Effect of foliar application of Zn and Mn on HI in maize.
Means by the uncommon letter in each column are significantly different ($p < 0.05$)

Drought stress is one of the deleterious abiotic stresses for yield and other yield components in all crops. However in some crops such as maize foliar application of micronutrients was more useful rather than soil application of them as top dressing. In the present study 7 day irrigation period produced highest grain yield and its components in maize and more distance between irrigation periods such as 21 day irrigation period was deleterious for yield and its components in maize. Samarah et al (2004) told that drought stress is deleterious for plant growth, yield and mineral nutrition. However, the results of this study revealed that the effect of drought stress and foliar application of Zn and on all traits were significant but the interaction effect of them on 100-grain weight and grain yield were significant only (table 2). However, reduction in plant height, number of row per cob and number of grain per cob under water stress treatments was founded that may be attributed to the limitation of dry matter partitioning to the reproductive sink or even grain formation factors as has been reported by Turk et al (1980). Combined application of Zn and Mn fertilizers had a more positive effect on yield and yield components of maize. Plant height in combined application of Mn and Zn fertilizers was more than single application of them and control in non stress condition (fig 1). Soil moisture status during the reproductive phase of

crops plays an important role to determine the impact of yield component in final grain yield (Singh and Bhushan, 1980). Water stress can decrease number and shape of root hairs (Worrall & Roughley, 1976), nitrogenase activity and synthases of: sucrose, glutamate and glutamine (Ramos et al., 1999) that laid to the reduce of photosynthetic accumulation and plant height. In the present study the number of row and grain per cob in 7 day irrigation period giving more than 21 day irrigation period significantly. Maximum number of row and grain per plant founded at Zn+Mn fertilizer in 7 days irrigation period and this treatment had significant difference with single and non-application of Mn and Zn fertilizers in 14 and 21 days irrigation period.

The results showed that, application of Mn and Zn treatments in 7 day irrigation period treatment had the highest 100-grain weight and single and non application of any of Zn and Mn in 21 day irrigation period treatment had the lowest 100-grain weight. In soybean water stress will reduce net assimilation rate, root length, root dry weight, root-canopy ratio, number of roots, plant height, plant dry weight, number of pods and weight of 100 seeds (Kiyatno, 1993). Sariyah (1992) stated that increasing of water stress will decrease of leaf water potential, relative growth rate, dry seed weight, plant height, number of pods and seed yield per plant. In the present study

application of Zn and Mn fertilizer specially Zn+Mn treatment rather than other treatments decreased negative effects of drought stress in 14 and 21 days irrigation period.

Water plays an important role in the translocation of nutrients within the plant. Leaves as a source assimilate and act as seed storage. However reduction of water availability laid to the reduction of grain and biomass yield in all crops. Pandey et al (2002) stated that the maximum water consumption by the corn is almost when silk rating or immediately after that. Water deficit when tasselling and silk rating along with decreased grain number per ear decreases grain yield the most. The role of water for the plants have consequences directly or indirectly, plant water deficit will affect the plant metabolism by resulting in impaired growth (Pugnaire and Pardos, 1999). During seed development, assimilate transported from leaves to seeds. Other influences of water stress resulting assimilate movement speed decrease. Biomass and grain yield, however and harvest index decreased by increasing of irrigation period and Zn and Mn fertilizers had the positive effect on them. However, Serraj and Sinclair (1998) founded that a large variation in sensitivity to water deficit, among soybean cultivars, can be related to nodule formation and growth, and soybean genotypes can be selected for N₂

fixation and tolerance to water deficits. In the present study 7 days irrigation period treatment had the highest biomass yield and 21 day irrigation period treatment had the lowest biomass yield and combined application of Mn and Zn had the positive effect on this treatment. Decrease biomass yield under lower soil moisture might be due to reduction of leaf area and photosynthesis rate (Sinaki et al., 2007). In this study maximum production of grain yield was founded at application of Zn+Mn treatment in 7 day irrigation period treatment. With increasing of irrigation period grain yield was reduced in all treatments and application of Zn and Mn specially combined application of them increased grain yield production in maize. Decreasing in the growth variables observed of maize production due to increased drought stress due to suspected impaired nutrient transport from the leaves to the seeds. Drought occurrence in relation to anthesis stage causes a drastic reduction in yield and yield components. Seghatoleslami et al., (2008) told that the grain yield in the drought stress condition was restricted by limited moisture availability. The main cause of decreased grain yield in drought stress treatments seemed to be significant decrease in grain number per cob. Foliar application of Zn and Mn nutrient had a positive effect on the yield and yield

components of maize. In maize, the final grain yield is dependent on the number of cob per plant, number of grains per cob and the extent to which grains are filled. In the present study, the reduction in grain yield under water stress was associated with dramatic decrease in all yield components. The Zinc spraying under water stress conditions, had positive effect on growth, yield, and yield components of plants (Thalooth et al, 2006). The reduction in grain yield under drought stress to the secondary detrimental effects of drought avoidance on CO₂ assimilation. This result suggests that maize exhibit reproductive plasticity under drought stress conditions (Turk and Hall, 1980). The reduction in grain yield under water stress to the reduction in number of grain per plant, biomass yield and grain weight (Ludlow and Mushow, 1990; Gwathmey et al., 1992).

The comparison of the mean values of the harvest index for irrigation period showed that 7 day irrigation period treatment had the highest and 21 day irrigation period treatment had the lowest harvest index (fig 10). In foliar application of Zn and Mn treatments combined application of Zn and Mn treatment had the highest and control treatment had the lowest harvest index (fig 9). Harvest index determined followed by grain and biological yield. In the present study water stress decreased harvest index and this phenomenon showed that water

stress had the more negative effect on grain yield than biological yield that lead to the reduction of harvest index. Drought stress is a major factor affecting on crops and leads to decreased of growth, crop production and nodule formation (Tajima et al., 2004). Several mechanisms have been reported to be involved in the physiological response, carbon (C) shortage and oxygen limitation, that lead to the reduce of plant production (Zahran, 1999) that reduced biomass and grain yield and harvest index. The effect of water stress on HI to the reduction in assimilate supply attributed (Ziska and Hall, 1983).

The present study concluded that maximum production of yield and its components of maize was recorded for 7 days irrigation period and combined application of Mn and Zn fertilizers. Therefore, we can increase yield and yield components of maize by decrease of irrigation period and foliar application of Zn and Mn fertilizers specially combined application of them.

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