

**EFFECT OF INTEGRATED FOLIAR APPLICATION OF ZN AND FE ON YIELD AND
YIELD COMPONENTS OF MAIZE (*ZEA MAYS* L.) UNDER WATER STRESS CONDITION**

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ABSTRACT

A field experiment was laid out to determine the effects of irrigation period and foliar application of Zn and Fe nutrient on yield and yield components of maize (SC600 hybrid) on a loam clay soil, 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 Zn and Fe in three levels of (Zn+Fe with 1.5 in 1000 concentration, Zn with 2 in 1000 concentration and Fe with 2 in 1000 concentration) with control treatment in sub plots. Results showed that the effect of drought stress and foliar application of Zn and Fe nutrients on all traits were significant. However the interaction effect of drought stress and foliar application of Zn and Fe nutrients on 100 grain weight, grain yield and harvest index only. The comparison of the mean values of traits showed that 7 day irrigation period treatment had the highest plant height, number of row per cob, number of grain per cob and biomass yield and 21 day irrigation period treatment had the lowest of them. In foliar application of Zn and Fe treatments combined application of Zn+Fe treatment had the highest plant height, number of row per cob, number of grain per cob and biomass yield and control treatment had the lowest of them. However, the application of Zn+Fe treatment in 7 day irrigation period treatment had the highest 100-grain weight and grain yield and non application of any of Zn and Fe in 21 day irrigation period

treatment had the lowest of them. In final results showed that maximum production of maize was recorded for non drought stress treatment and was followed by application of foliar application of Zn+Fe nutrients, while severe water stress and non application of any of nutrients produced minimum production.

Key words: Drought stress, maize, Zn+Fe nutrients

INTRODUCTION

Foliar application of some nutrients as top dressing was more useful than soil application of them. Zn and Fe are considered to be two of the smallest nutritious elements for many organisms. Zinc plays an important role as a metal component of enzymes or as a functional, structural, or regulator cofactor of a large number of enzymes (Marschner, 1986). 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). Mahady (1990) found that foliar application of Zn SO for faba bean plants increased number of pods/plant and seed yield/fed. Soleimani (2006) reported increase in biological yield for foliar application of zinc. Fecenko and Lozek (1998) studied the effect of zinc sources on yield, protein percentage and macronutrient absorption in corn, and they witnessed that by three years of manure, the average amount of grain protein was

significantly increased. Torun et al. (2001) and 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 (Luo et al., 2000; Ottman et al., 2000). Marshner (1993) reported that, by increasing consumption of Iron and zinc in corn, we can witness that the total amount of carbohydrate and grain protein is increased, and as a result the gain weight, number of grains and at last yield will be increased as well. Tahmasebi et al (2003) declared that by increasing amounts of zinc, absorption of nitrogen will be decreased by the plant, yet potassium absorption will be increased. They also concluded that the most balanced status between nitrogen, phosphor and potassium absorption with 20 kilograms zinc sulfate per hectare was observed in saline soils.

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). 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). Therefore, the main cause of decreased grain yield in drought stress treatments seemed to be significant decrease in grain number per cob. Water loss in the plant tissue will decrease cell turgor, increasing the concentration of macro-molecules and water chemical compounds in plants (Mubiyanto, 1997). Several studies have also shown that optimum yield can be obtained with irrigation at branching, flowering and pod formation stages (Prihar and Sandhu, 1968). Dry 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). Kiyatno (1993) in soybean stated that 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. However, other researchers Sariyah (1992) stated that increasing water stress will decrease of leaf water potential, relative growth rate, dry seed weight, plant height, number of pods and seed yield per plant.

Therefore this study was planned to examine effect of irrigation period and foliar application of Zn and Fe nutrient on yield and yield components of maize (SC600 hybrid).

MATERIALS AND METHODS

A field experiment was laid out in order to evaluate the effects of drought stress, single and integrated application of Zn and Fe fertilizer on yield and yield components of maize (SC600 hybrid) 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)	Dept h
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 Zn and Fe in three levels of (Zn+Fe with 1.5 in 1000 concentration, Zn with 2 in 1000 concentration and Fe with 2 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 Fe on plant height was significant only (table 2). The comparison of the mean values of the plant height showed that 7 day irrigation period treatment had the highest (216cm) plant height and 21 day irrigation period treatment had the lowest (167cm) plant height (fig 1). In foliar application of Zn and Fe treatments combined application of Zn+Fe treatment had the highest (205cm) plant height and control treatment had the lowest (188cm) plant height and the differences were significant (fig 2).

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

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	58	1.59	3687	0.02	5.1	0.22	12.6
Irrigation (A)	2	812**	35.5**	15255**	269**	264**	137**	1532**
Ea	4	49	0.79	480	3	3.3	0.6	96
Foliar application of Zn and Fe (B)	3	423*	18.8**	16433**	40.5**	54**	25**	229**
A*B	6	58	2.1	898	9.27*	0.52	3.6**	96**
Eb	18	101	0.9	593	2.3	0.5	0.33	14
CV(%)		5.1	7.3	5.6	8	4.8	10.8	11.3

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

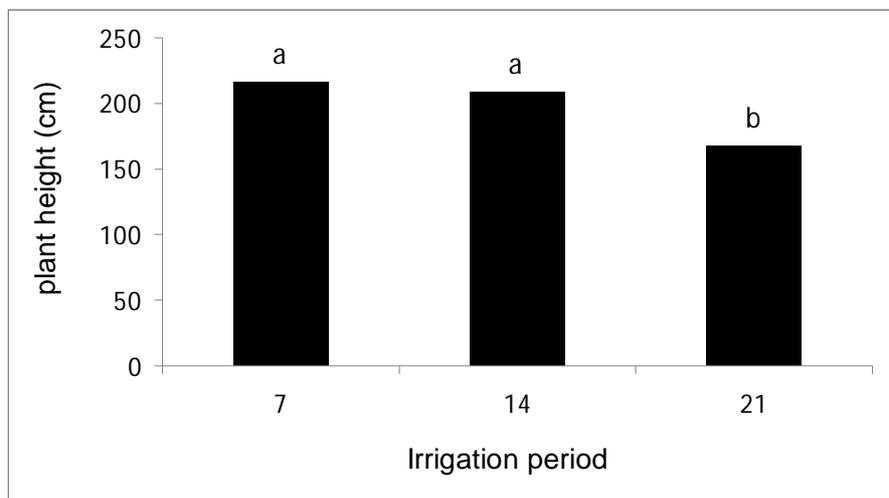


Figure 1: Effect of different irrigation period on plant height in maize. Means by the uncommon letter in each column are significantly different ($p < 0.05$)

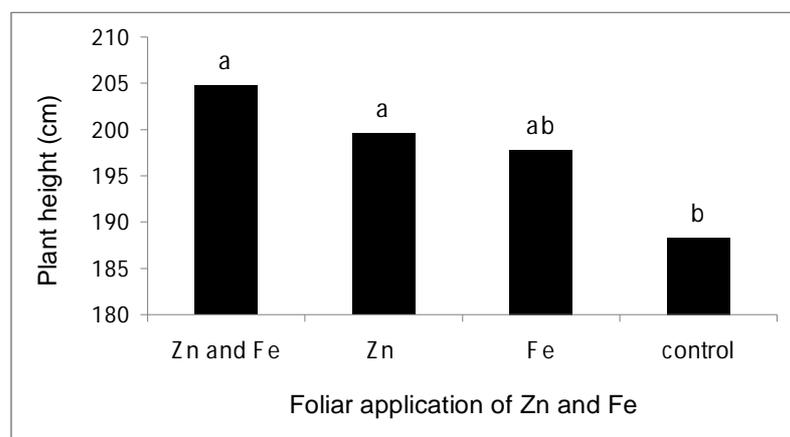


Figure 2: Effect of integrated application of Zn and Fe on plant height in maize. Means by the uncommon letter in each column are significantly different ($p < 0.05$)

Number of row per cob: The analysis of variance showed that the effect of irrigation period and application of Zn and Fe 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) number of

row per cob and 21 day irrigation period treatment had the lowest (11) number of row per cob (fig 3). In foliar application of Zn and Fe treatments combined application of Zn and Fe treatment had the highest (14.5) number of row per cob and control treatment had the lowest (10.3) number of row per cob and the differences were significant (fig 4).

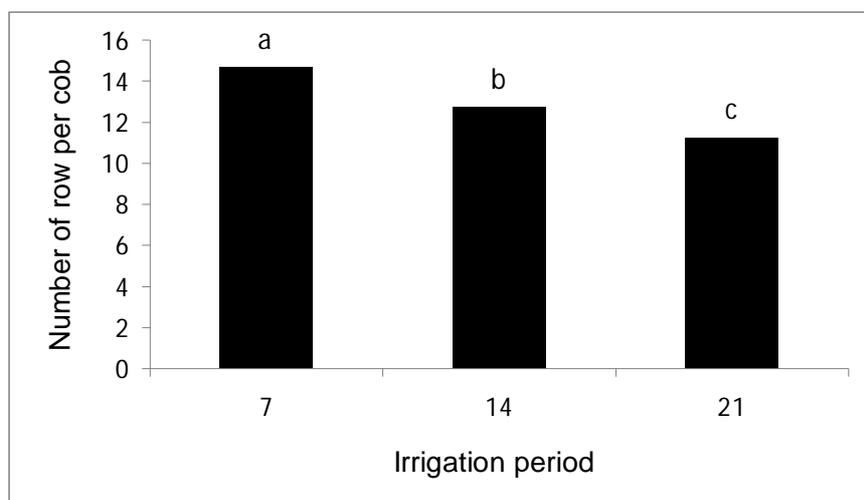


Figure 3. Effect of different irrigation period on number of row per cob in maize. Means by the uncommon letter in each column are significantly different ($p < 0.05$)

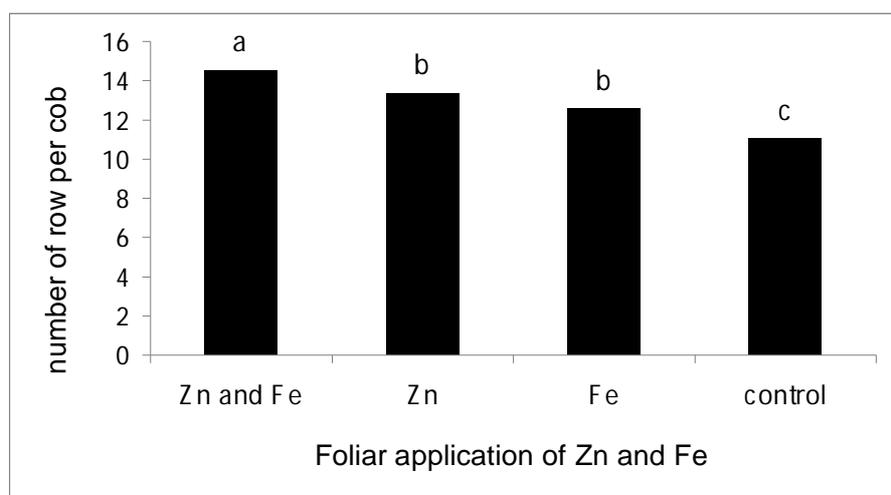


Figure 4: Effect of integrated application of Zn and Fe on number of row per cob in maize. Means by the uncommon letter in each column are significantly different ($p < 0.05$)

Number of grain per cob: The analysis of variance showed that the effect of irrigation period and application of Zn and Fe nutrient on number of grain per cob was significant (table 2). Also, 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 (530)

number of grain per cob and 21 day irrigation period treatment had the lowest (335) number of grain per cob (fig 5). In foliar application of Zn and Fe treatments combined application of Zn and Fe treatment had the highest (492) number of grain per cob and control treatment had the lowest (400) number of grain per cob (fig 6).

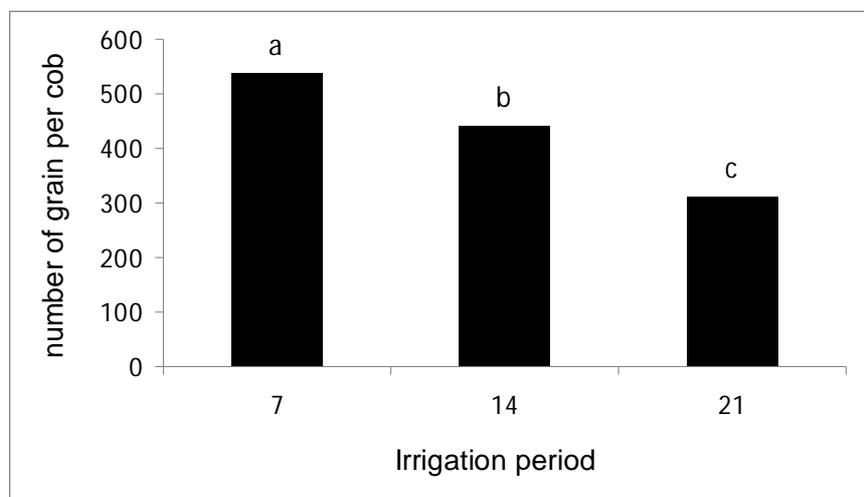


Figure 5. Effect of different irrigation period on number of grain per cob in maize. Means by the uncommon letter in each column are significantly different ($p < 0.05$)

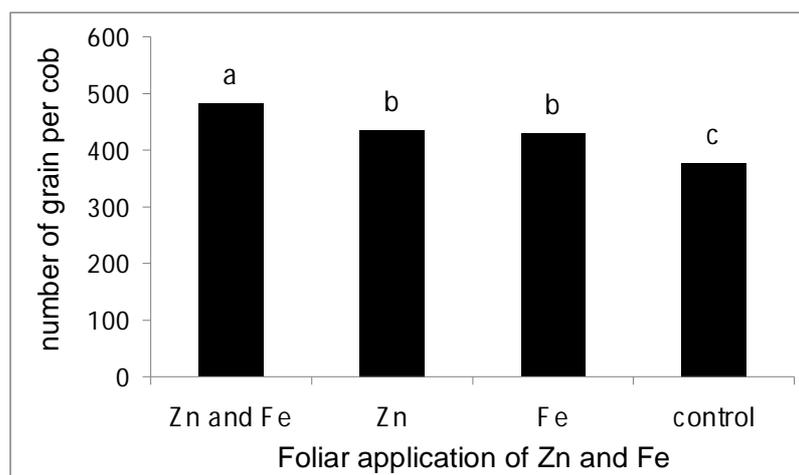


Figure 6: Effect of integrated application of Zn and Fe on number of grain per cob in maize. Means by the uncommon letter in each column are significantly different ($p < 0.05$)

100 grain weight: The results showed that the effect of irrigation period, application of Zn and Fe 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 Fe nutrient showed that application of Zn+Fe treatment in 7 day irrigation period treatment had the highest (27g) 100-grain weight and non application of any of Zn and Fe in 21 day irrigation period treatment had the lowest (14.5g) 100-grain weight (figure 7).

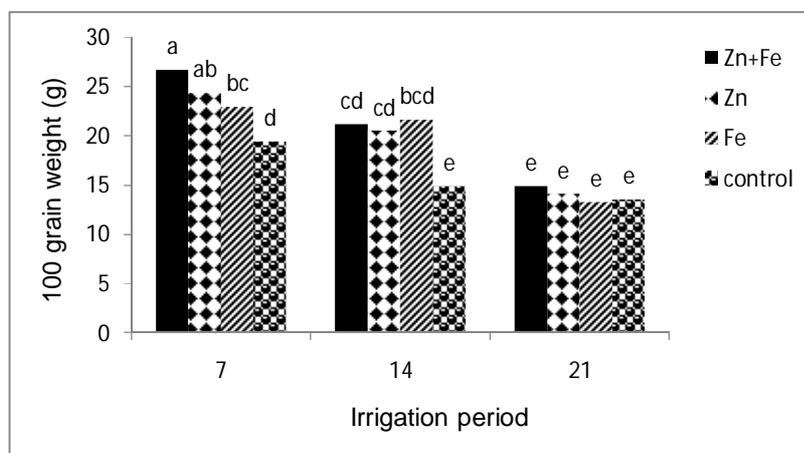


Figure 7: Effect of irrigation period and integrated application of Zn and Fe on 100 grain weight in maize
Means by the uncommon letter in each column are significantly different ($p < 0.05$)

Biomass yield: The analysis of variance showed that the effect of irrigation period and application of Zn and Fe nutrient on biomass yield was significant (table 2). Also, the comparison of the mean values of the biomass for irrigation period showed that 7 day irrigation period treatment had the highest (20 ton/ha) biomass yield and 21 day

irrigation period treatment had the lowest (10.5 ton/ha) biomass yield (fig 8). In foliar application of Zn and Fe treatments combined application of Zn and Fe treatment had the highest (17.2 ton/ha) biomass yield and control treatment had the lowest (11 ton/ha) biomass yield (fig 9).

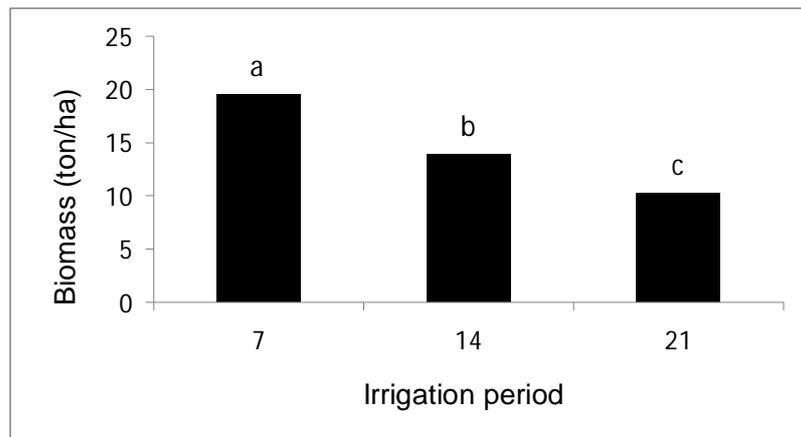


Figure 8. Effect of irrigation period on biomass yield in maize.
Means by the uncommon letter in each column are significantly different ($p < 0.05$)

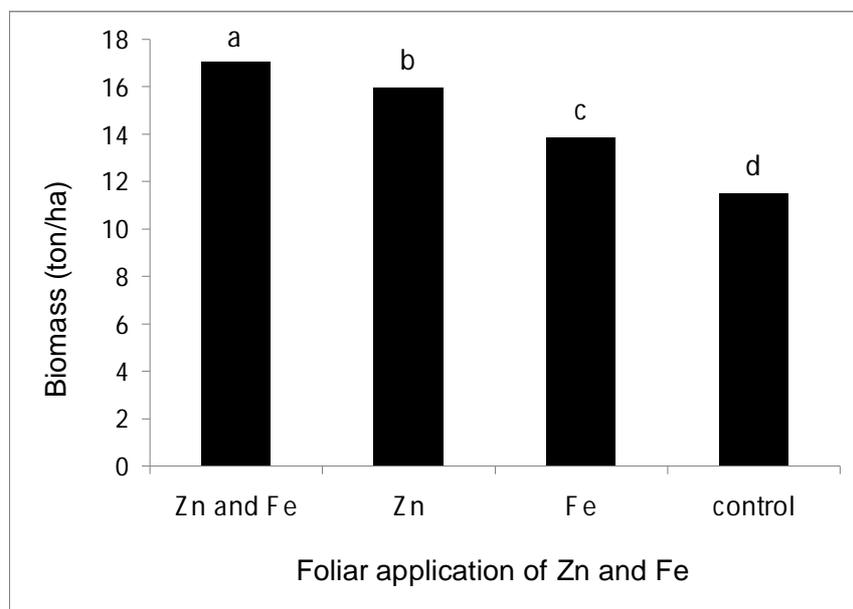


Figure 9: Effect of integrated application of Zn and Fe on biomass yield in maize
Means by the uncommon letter in each column are significantly different ($p < 0.05$)

Grain yield: The results showed that the effect of irrigation period, application of Zn and Fe nutrient 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+Fe treatment in 7 day irrigation period treatment had the highest (11.7 ton/ha) grain yield and non application of any of Zn and Fe in 21 day irrigation period treatment had the lowest (2 ton/ha) grain yield (fig 10).

Harvest index (HI): The effect of irrigation period, application of Zn and Fe nutrient and

interaction between them on harvest index were significant (table 2). The comparison of the mean values showed that application of Zn+Fe treatment in 7 day irrigation period

treatment had the highest (52%) harvest index and application of Zn nutrient in 21 day irrigation period treatment had the lowest (20%) harvest index (fig 11).

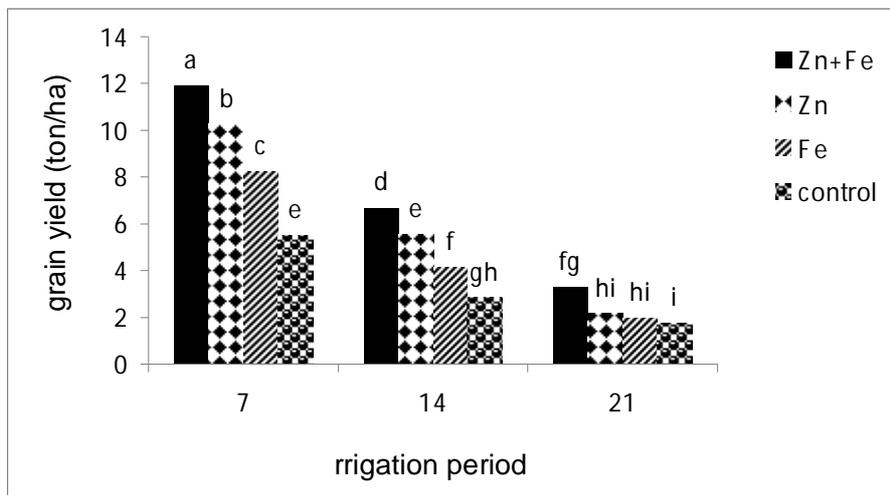


Figure 10: Effect of irrigation period and integrated application of Zn and Fe on grain yield in maize. Means by the uncommon letter in each column are significantly different (p<0.05)

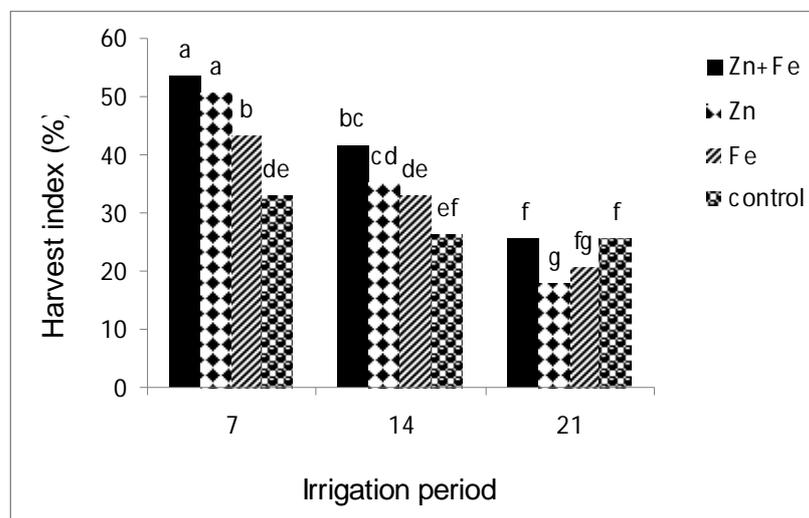


Figure 11: Effect of irrigation period and integrated application of Zn and Fe on harvest index in maize. Means by the uncommon letter in each column are significantly different (p<0.05)

Garg et al (2004) and 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, grain yield and harvest index were significant only (table 2). Mean comparison for all traits showed that showed that maize (SC 600 hybrid) grain yield and yield components decreased significantly with the increase of irrigation period but, increased with application of Zn and Fe specially Zn+Fe treatment. In the present study 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). However, Singh and Bhushan (1980) told that soil moisture status during the reproductive phase of crops plays an important role to determine the impact of yield component in final grain yield. The number of row and grain per cob in 7 day irrigation period giving more than 21 day irrigation period significantly. The significant reduction in number of total grains in plant under drought stress may be attributed to the abscission of the reproductive structures. Maximum number of row and grain per plant founded at Zn+Fe fertilizer and this treatment had

significant difference with other treatments. Ziska and Hall (1983) and Gwathmey and Hall (1992) reported similar results.

However in the present study results showed that, application of Zn+Fe treatment in 7 day irrigation period treatment had the highest 100-grain weight and non application of any of Zn and Fe in 21 day irrigation period treatment had the lowest 100-grain weight (figure 7). Kiyatno (1993) in soybean stated that 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. However, other researchers Sariyah (1992) stated that increasing 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 Fe fertilizer specially Zn+Fe treatment rather than other treatments decreased negative effects of drought stress in 14 and 21 days irrigation period.

Biomass and grain yield, however and harvest index decreased by increasing of irrigation period, but Zn and Fe fertilizers decreased this negative effects. For irrigation period showed that 7 day irrigation period treatment had the highest biomass yield and 21 day irrigation period treatment had the lowest biomass yield (fig 8). In foliar application of Zn and Fe treatments combined application of Zn

and Fe treatment had the highest biomass yield and control treatment had the lowest biomass yield (fig 9). Maximum production of grain yield and achieve to highest harvest index was founded at application of Zn+Fe treatment in 7 day irrigation period treatment. The grain yield in the drought stress condition was restricted by limited moisture availability. Drought occurrence in relation to anthesis stage causes a drastic reduction in yield and yield components (Seghatoleslami et al., 2008). 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. Water play an important role in the translocation of nutrients within the plant. Leaves as a source assimilate and act as seed storage. During seed development, assimilate transported from leaves to seeds. Other influences of water stress resulting assimilate movement speed decrease. Water loss in the plant tissue will decrease cell turgor, increasing the concentration of macromolecules and water chemical compounds in plants (Mubiyanto, 1997). 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). Therefore, the main cause of decreased grain yield in drought stress treatments seemed to be significant decrease in grain number per cob. In the present study, the reduction in grain yield under water stress was associated with dramatic decrease in all yield components. Thalooth et al (2006) reported that zinc spraying under water stress conditions, had positive effect on growth, yield, and yield components of plants. The findings of this experiment conformed to the results obtained by Sheykhbagloo et al (2009). This result was also supported by the other researchers (Mojadam, 2006 and Lack, 2006). 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. Folier application of Zn and Fe nutrient had a positive effect on the grain yield, biomass yield and yield components of maize. Positive effect of foliar application of these nutrients is due to synergistic effect of them on yield and yield components. Supporting evidences were reported by many researchers (Ziska and Hall, 1983; Ludlow and Mushow, 1990). They attributed the reduction in grain yield under water stress to the reduction in number of grain per plant, biomass yield and

grain weight. Turk and Hall (1980) attributed the reduction in grain yield under drought stress to the secondary detrimental effects of drought avoidance on CO₂ assimilation.

Harvest index was dramatically decreased with increased in irrigation period and non application of any Zn nutrient treatments. The comparison of the mean values showed that application of Zn+Fe treatment in 7 day irrigation period treatment had the highest harvest index and application of Zn nutrient in 21 day irrigation period treatment had the lowest harvest index (fig 11). Synergistic effect of Zn and Fe was affected on harvest index and both foliar application of them was more useful rather than single application of them.

CONCLUSION

Maximum production of maize was recorded for non drought stress treatment and was followed by application of foliar application of Zn+Fe nutrients, while severe water stress and non application of any of nutrients produced minimum production. Results of this experiment showed that application of Zn+Fe nutrient had better effect on grain yield and yield components compared to single application of them and control.

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