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The Relationship between Every-other Furrow Irrigation and Foliar Application of Zinc on Physiological Indices in Two Sweet Corn Genotypes

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ABSTRACT

To assessment growth physiological characteristics of two hybrids of sweet corn affected different irrigation pattern and zinc fertilization, a research was conducted as split plot factorial experiment based on randomized complete blocks design with three replications. Main factor included different levels of irrigation pattern included conventional furrow irrigation, fixed every other furrow irrigation and alternate every other furrow irrigation, also different levels of foliar application of zinc as lack of foliar application of zinc, use of Drop zinc sulfate (0.002 $lit.ha^{-1}$), use of fast zinc sulfate (0.002 $lit.ha^{-1}$) and two hybrids of sweet and super sweet corn belonged to sub plots. The result of analysis of variance indicated the effect of irrigation pattern, foliar application of zinc, different genotypes and interaction effect of the treatments on all measured traits were significant at 1% probability level. Dual interaction effect showed maximum rate of all physiological indices belonged to I_3Zn_3 (Alternate every other furrow irrigation, fast zinc spray), I_3V_2 (Alternate every other furrow irrigation, challenger genotype), Zn_3V_2 (Fast zinc spray, challenger genotype). According result of triple interaction effect maximum rate of physiological indices such as leaf area index (4.22), crop growth rate (3.19 $gr.m^{-2}$.GDD), relative growth rate (0.22 $gr.gr^{-1}$.GDD), net assimilation rate (1.73 $gr.m^{-2}$.GDD), chlorophyll a (0.90 $gr.gr^{-1}$ FW), chlorophyll b (0.49 $gr.gr^{-1}$ FW) and carotenoid (0.34 $gr.gr^{-1}$ FW) belonged to $I_3Zn_3V_2$ (Alternate every other furrow irrigation, fast zinc spray, challenger genotype). Finally use alternate every other furrow irrigation to conserve water along with foliar application of zinc (particularly zinc sulfate with fast zinc) led to stable physiological indices in stress conditions and it can be proposed to the farmers in Markazi province at central of Iran.

Keywords*:* *Chlorophyll, Growth curve, Irrigation, Micro elements.*

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INTRODUCTION

Sweet maize (*Zea mays* L. saccharata) is a vegetable crop with an important dietary significance. It has been consumed boiled, roasted or as adding to salads, pizzas and etc (Simic *et al*., 2012; Konstantinov and Andelkovic, 2007). Sweet corn is used as a fresh or processed vegetable; it contains higher kernel protein, oil, starch, sugar contents and many other nutrients than the other maize types (Aghayari *et al.,* 2016). Globally, irrigated corn is 17% of total acreage producing 40% of total grain yield (Popova *et al*., 1998). Corn is a high water demanding crop in all stages of its physiological development and can achieve high yields when water and nutrients are not limiting (Song and Dia, 2000). Drought is one of the factors, which threatens the agricultural products in most parts of the world. Shortage of water, on the other hand, is an important limiting factor in crop production. Alternate furrow irrigation is an ideal strategy to reduce irrigation water used. This method reduce the volume of water used up to 50 percent and induce a decrease in growth and yield due to the water stress caused by the smaller amount of applied irrigation in same irrigation frequency (Baybordi, 2006; Soriano *et al.,* 2004). Alternate furrow irrigation was proposed as a method to increase water use efficiency and decrease chemical leaching compared with every-furrow irrigation and with small yield losses for different crops compared with fixed furrow irrigation system (Mailholl *et al*., 2001). Alternate furrow irrigation (AFI) is a method whereby water is applied to every other furrow rather than to every furrow. Therefore, less water is usually applied with alternate furrow irrigation methods. Since a reduced amount of water applied (gross water application) does not consistently reduce yields, water use efficiency may be increased (Graterol *et al*., 1993). Alternate furrow irrigation has been widely applied worldwide to improve irrigation efficiency with good results in corn, sorghum, potato, cotton and peppermint (Kang *et al*., 2000; Sepaskhah and Khajehabdollahi, 2005). Irrigating plants at alternate furrows allows water to be applied to bigger areas than irrigating every furrow from a given water source for a given period than irrigating them at every furrows (Yonts *et al*., 2007). Nasri *et al*. (2010) reported increase frequent irrigation intervals alleviate water stress effect on yield and yield components. In addition, alternate furrow irrigation methods may supply water in a manner that greatly reduces the amount of surface wetted, leading to less evapotranspiration and less deep percolation (Graterol *et al*., 1993). Generally, alternate furrow irrigation regime has been found to be a trade-off; "a lower yield for a higher water use efficiency", in which water has been saved mainly by reduced evaporation from the soil surface (Kang *et al*., 2000; Stone and Nofziger, 1993). Graterol *et al*. (1993) reported that approximately same yield levels were obtained under both practices in soybeans, with significantly less water (46%) applied under every other furrow irrigation. Yonts *et al*. (2007) reported that water application can be reduced by 20 to 30% through every other row irrigation while corn yield was not much reduced. Baker *et al*. (1997) reported that the use of alternate furrow irrigation reduced sugar cane yield when the same irrigation frequency was applied as every furrow irrigation. The water requirements of corn on a fine textured soil (with deep and shallow water table) were not met by alternate furrow irrigation even at 4-day irrigation intervals (Sepaskhah and Khajehabdollahi, 2005). Sepaskhah and

Khajehabdollahi (2005) reported that decrease in corn yield due to water stress in AFI was mainly due to the decrease in the number of kernels per cob and to a lesser extent to the decrease in 1000-kernel weight. Water stress on maize has been shown to reduce plant height, diameter of shank, leaf area index and root growth (Wilson *et al.*, 2006). Rafiee (2012) showed that using every other furrow irrigation (FFI and AFI) caused water stress in corn and decreased photosynthetic pigments (chlorophyll a, chlorophyll b and chlorophyll a+b) and soluble protein, but antioxidants (catalase and peroxidase) and proline activity as biochemical markers for water stress raised in drought condition. 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). When plant access to elements such as B, K and Zn the growth of root and also the proportion of shank: root increases thus producing more carbohydrates and proteins enabling the plant to utilize the humidity of soil more efficiently specifically during drought periods (Parasad and Power, 2002). This research was conducted to evaluation effect of different irrigiation patterns and zinc fertilizer rate on physiological indices of sweet corn genotypes.

MATERIALS AND METHODS

Field and treatment information

This research was conducted to evaluate growth physiological indices of two hybrids of sweet corn under deficit irrigation and foliar application of zinc compounds in the experimental field of Arak Branch, Islamic Azad University, Markazi Province, center of Iran (34°40′ N 58°25′ E and height of 1150 m) via a factoriel split plot experiment based on randomized complete blocks design with three replications during 2015. The main factor including irrigiation patterns at three levels of conventional furrow irrigation (I_1), fixed every other furrow irrigation (I_2) and alternate every other furrow irrigation (I_3) and different levels of foliar application of zinc include; without zinc spray (control) (Zn_1), drop zinc spray (0.002 $Lit.ha^{-1}$) (Zn_2) and fast zinc spray (0.002 $Lit.ha^{-1}$) (Zn_3) with Chase (V_1) and Challenger (V_2) as sweet corn genotypes belonged to sub factor. Generally, there were 36 subsidiary plots with 20 m^2 surface area. 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 (Table 1); required fertilizer was added to farmland. 150 kg of urea, 150 kg of super phosphate and 100 kg of potassium soleplate per hectare were added to soil. Meteorological information of Arak field research during 2015 was showen in table 2.

Table 1. Soil properties of the research field

Soil texture	Loam	**Cu (ppm)**	1.04	**K (ppm)**	400.00	**SP (%)**	31.00
Clay (%)	22.4	**Mn (ppm)**	6.72	**P (ppm)**	25.60	**pH**	7.70
Silt (%)	35.0	**Zn (ppm)**	4.16	**N (%)**	0.15	**EC ($ds.m^{-1}$)**	1.20
Sand (%)	41.0	**Fe (ppm)**	2.98	**O.C (%)**	1.50	-	-

OC: Organic Carbon, SP: Soil porosity, pH: potential hydrogen, EC: Electerical Conductivity.

Table 2. Meteorological data of field research during the growing season in 2014

Climatic Factor	May	Jun.	Jul.	Aug.	Sep.	Oct.
Precipitation (mm)	9.3	0	0	0	0	1.1
Mean temperture (°C)	20.3	26.	31.1	29.7	24	19
Mean Max. Temp. (°C)	28.9	36.3	40.6	39.1	34.6	28.6
Mean Min. Temp. (°C)	11.3	15.6 9	20.2	19.5	12.7	9.9
Relative hummididty (%)	40	22	20	22	23	28

Traits measurements

Growth Curves: Each plot was harvested at maturity stage for mesured leaf area index (LAI), dry matter, crop growth rate (CGR), net assimilation rate (NAR), relative growth rate (RGR) and harvest index (HI) according to below equations:

Equation 1. LAI=LA/SA.

Equation 2. $CGR = (W2 - W1)/(t_2 - t_1) * \frac{1}{GA}$

Equation 3. $NAR = \frac{CGR}{LAI}$

Equation 4. $RGR = (Ln W2 - Ln W1)/(t_2 - t_1)$

Equation 5. $HI = \frac{Ye}{Yb}.100$

GA= ground area, W_1= total dry matter at time T_1, W_2= total dry matter at time T_2, LA= Total leaf area, LA_1= Total leaf area at time T_1, LA_2= Total leaf area at time T_2, Ln= Natural logarithm, Y_e= Economic yield, Y_b= Biologic yield.

Chlorophylls and carotenoids assay: chlorophyll a (Chl. a) and chlorophyll b (Chl. b) and carotenoids (Car.), were determined spectrophotometrically, using 80% acetone as a solvent (Lichtenthaler, 1987). The pigment extract was measured against a blank of 80% (V/V) acetone at wavelengths of 647 and 663 nm for chlorophyll assays and at wavelengths of 470 for carotenoids. Finally, amounts of traits, was determined by the following formula.

Equation 6. Chl. a= 12.25 × A663 − 2.79 × A647

Equation 7. Chl. b= 21.50 × A647 − 5.10 × A663

Equation 8. Carotenoid= (1000 A470 – 1.82 Chl. a – 85.02 Chl. b)/189.

A is the absorbance of wavelength, after the correction for scattering at 750 nm (Zivcak *et al*., 2014).

Statistical Analysis

Analysis of variance and mean comparisons were done via SAS software (Ver.8) and Duncan multiple range test at 5% probability level.

RESULT AND DISCUSSION

Leaf Area Index (LAI)

The result of analysis of variance indicated the effect of irrigation pattern, foliar application of zinc, different genotypes and interaction effect of treatments on leaf area index were significant at 1% probability level (Table 3). Dual interaction effect of irrigation pattern and zinc fertilizer showed treatments of I_3Zn_3 (Alternate every other furrow irrigation and fast zinc spray) had higher leaf area index (4.26) than other tratments (Table 4). Dual interaction effect of irrigation pattern and genotypes showed treatments of I_3V_2 (Alternate every other furrow irrigation and Chalenger) had higher leaf area index (4.21) than other tratments (Table 5). Dual interaction effect of zinc fertilizer and genotypes showed treatments of Zn_3V_2 (Fast zinc spray and Chalenger) had higher leaf area index (3.93) than other tratments (Table 6). These findings are in agreement with Earl *et al*. (2003) and Friedrik (2012) who investigated the effect of drought stress on mustard and wheat.

Table 3. Result of analysis of variance of measured traits

S.O.V	df	LAI	CGR	RGR	NAR	Chlorophyll a	Chlorophyll b	Carotenoid
Replication	2	0.41**	5.16 n.s	22.72 **	0.78 n.s	0.001ns	0.003 ns	0.006ns
I	2	1.03 **	1657.09**	201.69 **	10.55 **	0.230**	0.039**	0.020*
Zn	2	0.95 **	347.139**	220.15 **	12.43 **	0.065**	0.068**	0.048*
I*Zn	4	0.10 **	85.18**	39.98 **	2.84 **	0.003**	0.055**	0.015**
Error I	4	0.04	48.01	1.55	0.30	0.004	0.002	0.008
V	1	0.94 **	87.28**	4.85 **	0.66 **	0.305**	0.058**	0.095**
I*V	2	0.23 **	73.59**	4.004 **	0.39 **	0.041*	0.016**	0.019**
Zn*V	2	0.13 **	89.94**	6.62 **	0.44 **	0.0073**	0.029**	0.016**
I*Zn*V	4	0.11 **	67.15**	2.19 **	0.41 **	0.021**	0.021**	0.018**
Error II	30	0.009	0.35	0.60	0.08	0.002	0.003	0.003
CV (%)		12.63	13.68	13.41	11.28	6.12	4.67	7.12

ns, * and **: non –significant at the 5% and 1% levels, respectively. **I**: Irrigation, **Zn**: Zinc fertilizer, **V**: Genotype

Table 4. Mean comparison of interaction effects irrigation pattern and zinc fertilizer on physiological indices

Treatment	LAI	CGR ($gr.m^{-2}.GDD$)	RGR ($gr.gr^{-1}.GDD$)	NAR ($gr.m^{-2}.GDD$)	Chlorophyll a ($gr.gr^{-1}$ FW)	Chlorophyll b ($gr.gr^{-1}$ FW)	Carotenoid ($gr.gr^{-1}$ FW)
I_1Zn_1	3.56 b*	3.11 b	0.11 c	1.63 a	0.89 a	0.47 a	0.30 a
I_1Zn_2	3.60 b	3.11 b	0.12 c	1.61 a	0.86 a	0.41 a	0.31 a
I_1Zn_3	4.25 a	3.18 a	0.18 a	1.71 a	0.84 a	0.47 a	0.30 a
I_2Zn_1	3.31 c	3.09 b	0.12 c	1.32 b	0.64 b	0.37 b	0.21 b
I_2Zn_2	3.21 c	3.08 b	0.15 b	1.28 b	0.68 b	0.31 b	0.22 b
I_2Zn_3	3.42 b	3.08 b	0.15 b	1.33 b	0.69 b	0.32 b	0.22 b
I_3Zn_1	3.61 b	3.12 b	0.12 b	1.59 a	0.87 a	0.41 a	0.31 a
I_3Zn_2	3.48 c	3.14 a	0.14 bc	1.61 a	0.87 a	0.47 a	0.30 a
I_3Zn_3	4.26 a	3.18 a	0.18 a	1.72 a	0.89 a	0.47 a	0.32 a

* According to Duncan's multi range test, Means with the same letters in each column was not significant difference (P≤0.01).

I_1: Conventional furrow irrigation, **I_2**: Fixed every other furrow irrigation, **I_3**: Alternate every other furrow irrigation

Zn_1: Without zinc spray (Control), **Zn_2**: Drop zinc spray (Equivalent 0.002 $Lit.ha^{-1}$), **Zn_3**: Fast zinc spray (Equivalent 0.002 $Lit.ha^{-1}$).

Table 5. Mean comparison of interaction effects Irrigation pattern and genotypes on physiological indices

Treatment	LAI	CGR ($gr.m^{-2}.GDD$)	RGR ($gr.gr^{-1}.GDD$)	NAR ($gr.m^{-2}.GDD$)	Chlorophyll a ($gr.gr^{-1}$ FW)	Chlorophyll b ($gr.gr^{-1}$ FW)	Carotenoid ($gr.gr^{-1}$ FW)
I_1V_1	3.86 b*	3.13 a	0.14 b	1.58 a	0.86 a	0.41 a	0.32 a
I_1V_2	3.67 b	3.13 a	0.14 b	1.64 a	0.84 a	0.41 a	0.31 a
I_2V_1	3.21 c	3.09 b	0.10 c	1.31 b	0.64 b	0.37 b	0.22 b
I_2V_2	3.45 c	3.08 b	0.10 c	1.38 b	0.68 b	0.31 b	0.22 b
I_3V_1	3.76 b	3.15 a	0.15 b	1.65 a	0.87 a	0.32 b	0.31 a
I_3V_2	4.21 a	3.16 a	0.16 a	1.69 a	0.88 a	0.42 a	0.21 b

* According to Duncan's multi range test, Means with the same letters in each column was not significant difference (P≤0.01).

I_1: Conventional furrow irrigation, **I_2**: Fixed every other furrow irrigation, **I_3**: Alternate every other furrow irrigation

V_1: Chase Genotype, **V_2**: Challenger Genotype

Triple interaction effect of treatments indicated that maximum LAI belonged to $I_3ZN_3V_2$ treatment (Alternate irrigation, fast zinc and Challenger genotype) by 4.22 and the lowest belonged to $I_2Zn_2V_2$ treatment (Furrow irrigation, without zinc and Challenger genotype) by 3.20 that were significantly different at 1% probability level (Table 7). This finding was in agreement with the results of Ashraf (2009). Moreover, Zn application for sweet corn by Ahmadi *et al.* (2013) led to increase of LAI which was in agreement with our results.

Crop Growth Rate (CGR)

The result of analysis of variance showed the effect of irrigation pattern, foliar application of zinc, different genotypes and interaction effect of treatments on crop growth rate were significant at 1% probability level (Table 3). Dual interaction effect of irrigation pattern and zinc fertilizer showed treatments of I_3Zn_3 (Alternate every other furrow irrigation and fast zinc spray) had higher crop growth rate (3.18 $gr.m^{-2}$.GDD) than other tratments (Table 4). Dual interaction effect of irrigation pattern and genotypes showed treatments of I_3V_2 (Alternate every other furrow irrigation and Chalenger) had higher crop growth rate (3.16 $gr.m^{-2}$.GDD) than other tratments (Table 5). Dual interaction effect of zinc fertilizer and genotypes showed treatments of Zn_3V_2 (Fast zinc spray and Chalenger) had higher crop growth rate (3.15 $gr.m^{-2}$.GDD) than other tratments (Table 6). These findings are in agreement with Earl *et al*. (2003), Friedrik (2012) who investigated the effect of drought stress on mustard and wheat. Another researchesrs such as Benjamin and Ritchie (2007) confirmed that result. According result of triple interaction effect of treatments the maximum CGR belonged to $I_3ZN_3V_2$ treatment (Alternate irrigation, fast zinc and Challenger) by 3.19 ($gr.m^{-2}$.GDD) and the lowest belonged to $I_2Zn_1V_1$ treatment (Furrow irrigation, without zinc and Chase hybrid) by 3.11 ($gr.m^{-2}$.GDD) that were significantly different at 1% level (Table 7). Zn application for sweet corn by Yazdani *et al*. (2007) has led to the increase of CGR in agreement with our results. Also Alizadeh *et al*. (2007) and Scot and Aboudrare (2009) reported that drought stress can be substantially reduced growth rate of the product and thereby reduce plant biomass.

Relative Growth Rate (RGR)

According to the result of analysis of variance effect of irrigation pattern, foliar application of zinc, different genotypes and interaction effect of treatments on relative growth rate were significant at 1% probability level (Table 3). Dual interaction effect of irrigation pattern and zinc fertilizer showed treatments of I_3Zn_3 (Alternate every other furrow irrigation and fast zinc spray) had higher relative growth rate (0.18 $gr.gr^{-1}$.GDD) than other tratments (Table 4). Dual interaction effect of irrigation pattern and genotypes showed treatments of I_3V_2 (Alternate every other furrow irrigation and Chalenger) had higher relative growth rate (0.16 $gr.gr^{-1}$.GDD) than other tratments (Table 5). Dual interaction effect of zinc fertilizer and genotypes showed treatments of Zn_3V_2 (Fast zinc spray and Chalenger) had higher crop growth rate (0.15 $gr.gr^{-1}$.GDD) than other tratments (Table 6). These findings are in agreement with Reynold *et al.* (2014) and William (2007) who investigated that CGR on corn decrease dramatically between 30 and 50% by drought stress in semi ard area in Kanzas. Result of interaction effect of treatments indicated that maximum RGR belonged to $I_3ZN_3V_2$ treatment (Alternate irrigation, fast zinc and Challenger hybrid) by 0.22 ($gr.gr^{-1}$.GDD) and the lowest belonged to $I_2Zn_2V_1$ treatment (Furrow irrigation, Drop zinc and Chase hybrid) by 0.10 ($gr.gr^{-1}$.GDD) that were significantly different at 1% level. This finding was in agreement with the results of Majidian and Ghadiri (2002) and Sanders and Shaw (2014), they reported that differences in relative growth rate in irrigation patterns because of water absorption was good especially in the reproductive stages of maize.

Table 6. Mean comparison of interaction effects of Zinc fertilizer and genotypes on physiological indices

Treatment	LAI	CGR ($gr.m^{-2}.GDD$)	RGR ($gr.gr^{-1}.GDD$)	NAR ($gr.m^{-2}.GDD$)	Chlorophyll a ($gr.gr^{-1}$ FW)	Chlorophyll b ($gr.gr^{-1}$ FW)	Carotenoid ($gr.gr^{-1}$ FW)
Zn_1V_1	3.50^{b}	3.11^{b}	0.12^{b}	1.32^{c}	0.67^{c}	0.32^{b}	0.21^{c}
Zn_1V_2	3.17^{b}	3.10^{b}	0.12^{b}	1.38^{c}	0.65^{c}	0.31^{b}	0.31^{a}
Zn_2V_1	3.52^{b}	3.11^{b}	0.12^{b}	1.54^{b}	0.75^{b}	0.37^{b}	0.22^{b}
Zn_2V_2	3.62^{a}	3.11^{b}	0.11^{b}	1.59^{b}	0.79^{b}	0.31^{b}	0.22^{b}
Zn_3V_1	3.80^{a}	3.15^{a}	0.15^{a}	1.63^{b}	0.88^{a}	0.42^{a}	0.31^{a}
Zn_3V_2	3.93^{a}	3.15^{a}	0.15^{a}	1.71^{a}	0.89^{a}	0.43^{a}	0.33^{a}

* According to Duncan's multi range test, Means with the same letters in each column was not significant difference ($P \leq 0.01$).

Zn_1: Without zinc spray (Control), **Zn_2**: Drop zinc spray (Equivalent 0.002 $Lit.ha^{-1}$), **Zn_3**: Fast zinc spray (Equivalent 0.002 $Lit.ha^{-1}$).

V_1: Chase Genotype, **V_2**: Challenger Genotype.

Table 7. Mean comparison of triple interaction effects of treatments on physiological indices

Treatment	LAI	CGR ($gr.m^{-2}.GDD$)	RGR ($gr.gr^{-1}.GDD$)	NAR ($gr.m^{-2}.GDD$)	Chlorophyll a ($gr.gr^{-1}$ FW)	Chlorophyll b ($gr.gr^{-1}$ FW)	Carotenoid ($gr.gr^{-1}$ FW)
$I_1Zn_1V_1$	3.87^{b}	3.11^{b}	0.17^{b}	1.61^{b}	0.55^{c}	0.47^{ab}	0.28^{b}
$I_1Zn_1V_2$	3.42^{c}	3.11^{b}	0.11^{b}	1.59^{b}	0.59^{c}	0.47^{ab}	0.27^{b}
$I_1Zn_2V_1$	3.66^{b}	3.12^{b}	0.13^{de}	1.62^{b}	0.58^{c}	0.47^{ab}	0.29^{a}
$I_1Zn_2V_2$	3.53^{c}	3.11^{b}	0.12^{b}	1.63^{b}	0.62^{c}	0.46^{ab}	0.30^{a}
$I_1Zn_3V_1$	4.16^{a}	3.18^{b}	0.18^{b}	1.68^{b}	0.64^{b}	0.48^{a}	0.32^{a}
$I_1Zn_3V_2$	4.05^{a}	3.19^{b}	0.18^{b}	1.69^{b}	0.56^{c}	0.48^{a}	0.31^{a}
$I_2Zn_1V_1$	3.20^{c}	3.11^{b}	0.12^{b}	1.28^{c}	0.74^{b}	0.33^{c}	0.32^{b}
$I_2Zn_1V_2$	3.53^{b}	3.07^{b}	0.13^{b}	1.41^{c}	0.73^{b}	0.32^{c}	0.29^{c}
$I_2Zn_2V_1$	3.50^{b}	3.07^{b}	0.10^{b}	1.43^{c}	0.72^{b}	0.30^{c}	0.29^{c}
$I_2Zn_2V_2$	3.20^{c}	3.08^{b}	0.19^{a}	1.46^{c}	0.79^{b}	0.32^{c}	0.32^{c}
$I_2Zn_3V_1$	3.22^{c}	3.08^{b}	0.10^{a}	1.48^{c}	0.80^{a}	0.31^{c}	0.30^{c}
$I_2Zn_3V_2$	3.63^{b}	3.08^{b}	0.20^{a}	1.52^{b}	0.82^{a}	0.31^{c}	0.29^{c}
$I_3Zn_1V_1$	3.46^{b}	3.12^{a}	0.12^{b}	1.63^{b}	0.81^{a}	0.44^{b}	0.31^{b}
$I_3Zn_1V_2$	3.75^{b}	3.13^{a}	0.13^{b}	1.65^{b}	0.84^{a}	0.44^{b}	0.32^{b}
$I_3Zn_2V_1$	3.79^{b}	3.14^{a}	0.14^{b}	1.66^{b}	0.88^{a}	0.44^{b}	0.33^{b}
$I_3Zn_2V_2$	3.23^{a}	3.14^{a}	0.14^{b}	1.66^{b}	0.87^{a}	0.45^{ab}	0.30^{b}
$I_3Zn_3V_1$	4.12^{a}	3.18^{a}	0.18^{b}	1.71^{a}	0.86^{a}	0.48^{a}	0.33^{a}
$I_3Zn_3V_2$	4.22^{a}	3.19^{a}	0.22^{a}	1.73^{a}	0.90^{a}	0.49^{a}	0.34^{a}

* According to Duncan's multi range test, the means of treatments with similar letters are not significantly different at 1% level.

I_1: Conventional furrow irrigation, **I_2**: Fixed every other furrow irrigation, **I_3**: Alternate every other furrow irrigation

Zn_1: Without zinc spray (Control), **Zn_2**: Drop zinc spray (Equivalent 0.002 $Lit.ha^{-1}$), **Zn_3**: Fast zinc spray (Equivalent 0.002 $Lit.ha^{-1}$).

V_1: Chase Genotype, **V_2**: Challenger Genotype.

Net Assimilation Rate (NAR)

The results of analysis of variance showed that the effect of irrigation pattern, foliar application of zinc, different genotypes and interaction effect of treatments on net assimilation rate were significant at 1% probability level (Table 3). Dual interaction effect of irrigation pattern and zinc fertilizer showed treatments of I_3Zn_3 (Alternate every other furrow irrigation and fast zinc spray) had higher NAR (1.72 $gr.m^{-2}.GDD$) than other tratments (Table 4). Dual interaction effect of irrigation pattern and genotypes showed treatments of I_3V_2 (Alternate every other furrow irrigation and Chalenger) had higher NAR (1.69 $gr.m^{-2}.GDD$) than other tratments (Table 5). Dual interaction effect of zinc fertilizer and genotypes showed treatments of Zn_3V_2 (Fast zinc spray and Chalenger) had higher NAR

(1.71 $gr.m^{-2}.GDD$) than other tratments (Table 6). These findings are in agreement with Rafie *et al*. (2003) and Friedrik (2012). According interaction effect of treatments maximum rate of NAR belonged to $I_3ZN_3V_2$ treatment (Alternate irrigation, fast zinc and Challenger) by 1.73 ($gr.m^{-2}.GDD$) and the lowest belonged to $I_2Zn_1V_1$ treatment (Furrow irrigation, without zinc and Chase) by 1.28 ($gr.m^{-2}.GDD$) that were significantly different at 1% level by 49.97%. This finding was in agreement with the results of Scot and Aboudrare (2009). Also Ahmadi *et al*. (2013) and Soleymanifard *et al*. (2011) reported that drought stress was effective in decrease of NAR and was significantly different from sulphate zinc and control treatment at 1% level.

Chlorophyll a

According to the result of analysis of variance effect of irrigation pattern, foliar application of zinc, different genotypes and interaction effect of treatments on chlorophyll a were significant at 1% probability level (Table 3). Dual interaction effect of irrigation pattern and zinc fertilizer showed treatments of I_3Zn_3 (Alternate every other furrow irrigation and fast zinc spray) had higher chlorophyll a (0.89 $gr.gr^{-1}$ FW) than other tratments (Table 4). Dual interaction effect of irrigation pattern and genotypes showed treatments of I_3V_2 (Alternate every other furrow irrigation and Chalenger) had higher Chlorophyll a (0.88 $gr.gr^{-1}$ FW) than other tratments (Table 5). Dual interaction effect of zinc fertilizer and genotypes showed treatments of Zn_3V_2 (Fast zinc spray and Chalenger) had higher chlorophyll a (0.89 $gr.gr^{-1}$ FW) than other tratments (Table 6). This finding was in agreement with the results of Benjamin *et al*. (2007). Triple interaction effect of treatments showed that maximum chlorophyll a belonged to $I_1ZN_3V_2$ treatment (Control irrigation, fast zinc and challenger) by 0.56 ($gr.gr^{-1}$ FW) and the lowest belonged to $I_2Zn_2V_1$ treatment (Furrow irrigation, drop zinc and chase) by 0.90 ($gr.gr^{-1}$ FW) that were significantly different at 1% level (Table 7). These findings are in agreement with Friedrick *et al*. (2012) and Ghatavi (2012) who investigated the effect of drought stress on corn. Zn application for sweet corn by Yazdani *et al*. (2006) has led to the increase of chlorophyll a in agreement with our results. Kaman *et al*. (2011) reported that drought stress can be substantially reduced chlorophyll a of the corn and thereby reduce plant biomass. Our result is in agreement with Shao *et al*. (2004) and Khayatnezhad and Gholamin (2011) who stated that chlorophyll could stops in severe water shortages.

Chlorophyll b

Result of analysis of variance indicated the irrigation pattern, foliar application of zinc, different genotypes and interaction effect of treatments on chlorophyll were significant at 1% probability level (Table 3). Dual interaction effect of irrigation pattern and zinc fertilizer showed treatments of I_3Zn_3 (Alternate every other furrow irrigation and fast zinc spray) had higher chlorophyll b (0.47 $gr.gr^{-1}$ FW) than other tratments (Table 4). Dual interaction effect of irrigation pattern and genotypes showed treatments of I_3V_2 (Alternate every other furrow irrigation and chalenger) had higher chlorophyll b (0.42 $gr.gr^{-1}$ FW) than other tratments (Table 5). Khayatnezhad and Gholamin (2012) and Moison (2006) reported similar results. Dual interaction effect of zinc fertilizer and genotypes showed treatments of Zn_3V_2 (Fast zinc spray and chalenger) had higher chlorophyll b

(0.43 $gr.gr^{-1}$ FW) than other tratments (Table 6). In examining the triple interaction effect of treatments was observed that the maximum chlorophyll b belonged to $I_3ZN_3V_2$ treatment (Alternate irrigation, fast zinc and challenger) by 0.49 ($gr.gr^{-1}$ FW) and the lowest belonged to $I_2Zn_2V_1$ treatment (Furrow irrigation, drop zinc and chase) by 0.30 ($gr.gr^{-1}$ FW) that were significantly different at 1% level (Table 7). Our result is in agreement with result of Ghatavi *et al*. (2012). Zn application for sweet corn by Yazdani *et al*. (2006) has led to the increase of chlorophyll b which was in agreement with our results.

Carotenoid

Result of analysis of variance showed that the irrigation pattern, foliar application of zinc, different genotypes and interaction effect of treatments on carotenoid were significant at 1% probability level (Table 3). Dual interaction effect of irrigation pattern and zinc fertilizer showed treatments of I_3Zn_3 (Alternate every other furrow irrigation and fast zinc spray) had higher Carotenoid (0.32 $gr.gr^{-1}$ FW) than to other tratments (Table 4). Dual interaction effect of irrigation pattern and genotypes showed treatments of I_1V_1 (Conventional furrow irrigation and chase genotype) had higher carotenoid (0.32 $gr.gr^{-1}$ FW) than to other tratments (Table 5). This finding was in agreement with the results of Rakers (2013), Rahnama *et al*. (2006) and Payero *et al*. (2009). Dual interaction effect of zinc fertilizer and genotypes showed treatments of Zn_3V_2 (Fast zinc spray and chalenger) had higher carotenoid (0.33 $gr.gr^{-1}$ FW) than to other tratments (Table 6). In result of triple interaction effect of treatments was observed that the maximum carotenoid belonged to $I_3ZN_3V_2$ treatment (Alternate irrigation, fast zinc and challenger) by 0.34 ($gr.gr^{-1}$ FW) and the lowest belonged to $I_2Zn_2V_1$ treatment (Furrow irrigation, drop zinc and chase) by 0.29 ($gr.gr^{-1}$ FW) that were significantly different at 1% level by 49.04% (Table 7). Some researcher such as Salardini *et al*. (2004) reported similar result. Loongenecker *et al*. (2009) and Layer and Clegg (2003) reported that drought stress is the most important parameter in decrease of carotenoid and were significantly different from mineral application.

CONCLUSION

Generally, the results of the research indicated that drought stress allied in irrigation treatments reduced leaf area index, crop growth rate, relative growth rate, net assimilation rate, and harvest index. The highest reduction in leaf area index was related to the stress resulting from alternate irrigation pattern, but the application of intermittent irrigation pattern, due to successive double-sided irrigation of the roots led to more effective absorption of irrigating water and consequently reduced the effects of drought stress. The highest reduction in crop growth rate, relative growth rate, net assimilation rate, and harvest index was related to the alternate irrigation pattern which was significantly different from the control irrigation at 1% probability level. However, in all cases the intermittent irrigation treatment could compensate for the water deficit of crops and was not different from alternate irrigation treatment. Finally use alternate every other furrow irrigation to conserve water along with foliar application of zinc, particularly zinc sulfate with fast zinc composition leads to the stable physiological indices in stress conditions and it can be proposed to the farmers in Markazi province (In central of Iran).

REFERENCES

Ahmadi, J., H. Zieinal, M. A. Rostami. and R. Chogun. 2013. Study of drought resistance in commercially late maturing dent corn hybrids. J. Agric. Sci. 31: 891-907. (Abstract in English)

Aghayari, F., F. Khalili. and M. R. Ardakani. 2016. Effect of deficit irrigation, partial irrigation and superabsorbent polymer on yield and yield components of corn (K.S.C.703). J. Soil and Water Soil Res. Conserv. 6(1): 1-14. (Abstract in English)

Alizadeh, O., E. Majedi, H. A. Nadian, Gh. Nourmohammadi. and M. R. Amerian. 2007. Effect of water stress and different nitrogen rates on phenology, growth and development of corn. J. Agric. Sci. Natural Res. 14: 116-120. (Abstract in English)

Ashraf, M. 2009. Biotechnological approach of improving plant salt tolerance using antioxidants as markers. Biotech. Adv. 27: 84-93.

Babaeian, M., M. Heidari. and A. Ghanbari. 2010. Effect of water stress and foliar micronutrient application on physiological characterstics and nutrient uptake in sunflower. Iranian J. Crop Sci. 12(4): 311-391. (Abstract in English)

Barker, D. M., S. R. Raine. and M. J. Robertson. 1997. A Preliminary investigation of alternate furrow irrigation for sugar cane production. Proc. Aust. Soc. Sugar Cane Tech. 20: 302-309.

Baybordi, A. 2006. Effect of Fe, Mn, Zn and Cu on the quality and quantity of wheat under salinity stress. J. Water and Soil Sci. 17: 140-150.

Benjamin, D. S. and J. T. Ritchie. 2007. Short and long-term responses of corn to a pre-anthesis soil water deficit. Agronomy J. 84: 107-113.

Earl, H. J. and R. F. Davis. 2003. Effect of drought stress on leaf and whole canopy radiation, use efficiency and yield of maize. Agronomy J. 95: 688-696.

Friedrik, R. 2012. Effect of water stress at different development stages on vegetative and reproductive growth of corn. Field Crops Res. 89: 1-16.

Ghatavi, R. F., B. C. Jackson, J. R. Kiniry. and G. F. Arkin. 2012. Water deficit timing effects on yield components in maize. Agron. J. 81: 61-65.

Graterol, Y. E., D. E. Eisenhauer. and R. W. Elmore. 1993. Alternate-furrow irrigation for soybean production. Agric. Water Manage. J. 24: 133-145.

Kaman, H., C. Kirda. and S. Sesveren. 2011. Genotypic differences of maize in grain yield response to deficit irrigation. Agric. Water Manage. 98: 801-807.

Kang, S., Z. Liang, Y. Pan, P. Shi. and J. Zhang. 2000. Alternate furrow irrigation for maize production in an arid area. Agric. Water Manage. J. 45: 267-274.

Karam, F. R., D. R. Lahoud. and R. Y. Masaad. 2007. Evaporation, seed yield and water use efficiency of drip irrigated sunflower under full and deficit irrigation conditions. Agric. Water Manage. 90(3): 213- 235.

Khayatnezhad, M. and R. Gholamin. 2012. The effect of drought stress on leaf chlorophyll content and stress resistance in maize cultivars. Afri. J. Microbiol. Res. 6(12): 2844-2848.

Layer, E. J. and M. O. Clegg. 2003. Using corn maturity to maintain grain yield in the presence of late season drought. J. Prod. Agri. 12: 400-405.

Lichtenthaler, H. K. 1987. Chlorophylls and carotenoids: pigments of photosynthetic biomembranes. Methods Enzym. J. 148: 350- 382.

Loongenecker, S. R., J. Jones. and R. K. Crookston. 2009. Effect of water deficit during grain filling on the pattern of maize kernel growth and development. Crop Sci. J. 27: 726-730.

Mailhol, J. C., P. Ruelle. and I. Nemeth. 2001. Impact of fertilisation practices on nitrogen leaching under irrigation. Irrigation Sci. J. 20: 139-147.

Majidian, M. and H. Ghadiri. 2002. Effect of water stress and different levels of nitrogen fertilizer during different growth stages on grain yield, yield components, water use efficiency and some physiological characteristics of corn (*Zea mays* L.). Iranian J. Agri. Sci. 33: 521-533. (Abstract in English)

Moison, M. A. 2006. Drought responses of tropical corn. Leaf area and yield components in field. Maydica. J. 35: 221-226.

Nasri, M., M. Khalatbari. and H. Aliabadi Farahani. 2010. The effect of alternate furrow irrigation under different nutritional element supplies on some agronomic traits and seed qualitative parameters in corn (*Zea mays* L.). J. Cereals and Oilseeds. 1(2): 17-23.

Parasad, R. and J. F. Power. 2002. Soil fertility for sustainable agriculture .CRC Press LTC, Australia. 110 pp.

Payero, J. O., D. D.Tarkalson, S. Irmak, D. Davison. and J. L. Petersen. 2009. Effect timing of the deficit-irrigation allocation on the corn evapotranspiration, yield and water use efficiency and dry mass. Agri. Water Manage. J. 96: 1387-1397.

Popova, Z., I. Varlev, V. Kutev. and E. Ikonomova. 1998. Irrigation and cropping techniques to prevent natural water pollution. Papers of the 1st Inter-Regional Conf. Environment-Water: Innovative Issues in Irrigation and Drainage. Lisbon. Portugal. Pp: 6-13.

Rafiee, M. 2012. Effect of every other furrow irrigation and planting density on physiological traits in corn. World Appl. Sci. J. 17(2): 189-193.

Rafie, M., P. Jaafari. and H. Mollahosseini. 2003. The effects of drought stress and plant density on yield and some agronomic traits of maize. J. Res. Agri. Sci. 2: 13-24. (Abstract in English)

Rahnama, S. R., M. Parsa, A. Nezami. and A. Ganjeali. 2006. The effects of drought stress at different phenological stages on growth indices of chickpea (*Cicer arietinum* L.) in greenhouse conditions. Iranian J. Pulses Res. 1(2): 69-80. (Abstract in English)

Rakers, J. 2013. Physiological bases for yield differences in selected maize cultivars from Central America. Field Crops Res. 42: 69-80.

Reynold, P. and M. E. Westgate. 2014. Water deficit affects receptivity of maize silks. Crop Sci. J. 33: 278-182.

Sanders, O. T. R. and M. Shaw. 2014. Temperature and soil water effects on maize growth, development, yield and forage quality. Crop Sci. J. 36: 341-348.

Scot, P. and A. Aboudrare. 2009. Adaptation of crop management to water-limited environment. Eur. J. Agron. 21: 433-446.

Sepaskhah, A. R. and M. H. Khajehabdollahi. 2005. Alternate furrow irrigation with different irrigation intervals for maize (*Zea mays* L.). Plant Prod. Sci. J. 8: 592-600.

Simic, M., J. Srdic, Z. Videnovic, Z. Dolijanovic, A. Uludag. and D. Kovacevic. 2012. Sweet maize (*Zea mays* L. saccharata) weeds infestation, yield and yield quality affected by different crop densities. Bulgarian J. Agri. Sci. 18(5): 668-674. In: Konstantinov, K. and V. Andelkovic. 2007. Science as sustainable development. Maize Research Institute. Belgrade, Serbia. pp: 25-43.

Shao, H. B., L. Y. Chu, C. Abdul-Jaleel. and C. X. Zhao. 2008. Water deficit stress induced anatomical changes in higher plants. C. R. Biol. J. 331: 215-225.

Soleymanifard, A., S. S. Pourdad, R. Naseri. and A. Mirzaei. 2011. Effect of planting patternon honological characteristics and growth indices of safflower (*Carthamus tinctorius* L.) in rainfed conditions. Iranian J. Crop Sci. 13(2): 282-298. (Abstract in English)

Song, F. B. and J. Y. Dia. 2000. Effect of drought stress on growth and development of female inflorescence and yield of maize. J. Jillian Agri. Univ. 22(1): 17-22.

Soriano M. A., F. Orgaz, F. J. Villalobos. and E. Fereres. 2004. Efficiency of water use of early plantings of sunflower. Eur. J. Agron. 21: 465–476.

Stone, J. F. and D. L. Nofziger. 1993. Water use and yields of cotton grown under wide-spaced furrow irrigation. Agric. Water Manage. J. 24: 27-38.

William, J. R. and M. E. Westgate. 2007. Maize kernel set at low water potential.I: Sensitivity to reduce assimilates during early kernel growth. Crop Sci. J. 31: 1189-1195.

Wilson, D. R., P. G. Ston. and R. N. Gillespie. 2006. Drought effects on water use, growth and yield sweet corn. Proc. 9th Aust. Agron. Conf. pp: 45-48.

Yazdani, F., I. Allahdadi, G. A. Akbari. and M. R. Behbahani. 2007. Impact of super absorbent polymer on yield and growth analysis of soybean (*Glycine max* L.), under drought stress condition. Pakistan J. Biol. Sci. 10(23): 4190-4196.

Yonts, C. D., D. E, Eisenhauer. and D. Varner. 2007. Managing furrow irrigation systems. Institute of Agriculture and Natural Resources, University of Nebraska. Research Report. 45 pp.

Zivcak, M., M. Brestic. and H. M. Kalaji. 2014. Photosynthetic responses of sun- and shade-grown barley leaves to high light: is the lower PSII connectivity in shade leaves associated with protection against excess of light? Photosynth Res. J. 119: 339–354.
Doi: 10.1007/s11120-014-9969-8.