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# Assessment Effect of Different Irrigation Regime and Fertilizer Combinations on Seed Yield, Radiation Use Efficiency and Biochemical Parameters of Corn

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**RESEARCH ARTICLE**


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## ABSTRACT

New irrigation methods under different nutritional element supplies for maize production was designed and tested for evaluate quantitative and qualitative parameters by split-plot arrangement according complete randomized block design with three replications. Different Irrigation regimes was belonged to main plots (Conventional furrow irrigation: CFI or $A_1$, Alternate furrow irrigation: AFI or $A_2$ and fixed furrow irrigation: FFI or $A_3$). Sub plots consisted ($B_1$): Nitrogen + Phosphorus + or N + P as Control (C), ($B_2$): Nitrogen + Phosphorus + Potassium or N + P + K, ($B_3$): Nitrogen + Phosphorus + Potassium + Zinc or N + P + K + Zn, ($B_4$): Nitrogen + Phosphorus + Potassium + Zinc + Boron or N + P + K + Zn + B and ($B_5$): Nitrogen + Phosphorus + Potassium + Zinc + Boron + Iron or N + P + K + Zn + B + Fe. Results of analysis of variance showed that the interaction effects of different irrigation regime and fertilizer combinations on the characteristics of N Concentration, P Concentration, K Concentration, N Uptake, P Uptake, K Uptake, Number of seeds per row, 1000 seeds weight, leaf area index (LAI), Radiation use efficiency, seed yield, biological yield, number of seeds per row, was significant at 5% probability level. Interaction effects of treatments of irrigation regime and fertilization indicate that the Zn foliar increased concentrations of these elements in the seed. The highest and lowest of N, P and K uptake, seed yield and LAI were 117.56, 42.73, 55.7 $kg.ha^{-1}$, 12950 $kg.ha^{-1}$ 3.86 and 113.42, 17.4, 16 $kg.ha^{-1}$, 8894 $kg.ha^{-1}$, 2.41 from Alternate furrow irrigation and (C+K, Zn, B, Fe) fertilizer treatment and fixed furrow irrigation and control respectively. The highest of light use efficiency were obtained from Alternate furrow irrigation and conventional furrow irrigation and (C+K, Zn, B, Fe) fertilizer treatment with 0.175 $kg.kcal^{-1}.m^{-2}$. In order to utilize the water sources efficiently and increase corn production under limited water supply, we propose the use of circular irrigation care along with instance, K, Zn, B and Fe fertilizer.

**Key words:** *Deficit irrigation, Leaf area index, Nutrient concentration.*

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## INTRODUCTION

One of limitation factor in agricultural plants production in dry areas in the water tension at growth step negative effect of water tension on corn growth depends on the time of tension occurrence, the intensity, plant growth and genotype step. Low irrigation in one of strategies to expert agricultural plant tillage and scrounge in water use which is a proper method to produce harvest in water shortage, generally in this method water performance is reduced cognizant to be compensated by enter tillage surface expansion and in many areas of America, India, Africa and many other lands which have water shortage, this method is prevalent (English and James, 1990). The limitation of water resources in arid and semi-arid areas was the main reason that we considered water as the most important material in the production lines, although people often do not obey the irrigation water consumption rules and regulations (Cakir, 2004). Innovations for saving water in irrigated agriculture and thereby improving water use efficiency are of paramount importance in water-scarce regions. Conventional deficit irrigation is one approach that can reduce water use without causing significant yield reduction (Kirda *et al*., 2005). Water deficit stress and mineral nutrient deficiencies often limit the productivity of corn. In many of the important corn growing regions of the world (Tandon, 2005). On the global scale, Maize has the third cultivation and output after wheat and rice. About 17 percent of the global area has under Irrigated agriculture (Cavero *et al*., 2006). During water shortage, plants that used the methods to obtain tolerance to water stress (Bartles and Villalobos, 2009). Deficit irrigation strategies were equally effective in saving irrigation water. Alternate furrow irrigation practice for rapeseed provides water use efficiency benefit compared to full irrigation. The value of benefits from water saving should be balanced with the value of yield reductions and the cost of implementing alternative irrigation system compared to conventional systems (Bahrani and Pourreza, 2016). Alternative furrow irrigation is commonly applied as part of a deficit irrigation program because it does not require the application of more than 50-70% of the water used in a fully irrigated program (Marshal *et al*., 2008). Alternate furrow irrigation was proposed as a method to increase water use efficiency and decrease chemical leaching compared to every-furrow irrigation and with small yield losses for different crops compared to a fixed furrow irrigation system (Abedi and Pakniyat, 2010). Tagheian-Aghdam *et al*. (2014) reported the alternative and fixed furrow irrigation treatments presented as the best solution for water saving in arid and semi-arid fields with 50% and 60% saving amount 6.9% and 14.22% reduction in corn biological yields. In some cases that a researcher has compared two methods of full irrigation and water deficit over some crops such as corn and shown that water deficit stress approximately increases the level of cultivated area and income up to 42% in comparison to full irrigation that is with reductions in water consumption, energy usage and other agricultural materials. The researcher has also found out the water deficit stress is a strategy to increase the economic efficiency (Kang *et al*., 2000). One of these methods is using nutritional element supplies such as potassium and zinc (Tisdalo, 2005). Productivity is often limited by periods of water deficit and in a number of regions zinc deficiency occurs, but the interaction between zinc nutrition and water stress has not been studied extensively (Khan *et al.*, 2004) .The amount of K uptake by plants is higher than any other mineral element except nitrogen; its catalytic role that activate about 60 enzymes in the plant is of special importance (Hodges, 2007). The relationship between potassium and protein is of particular importance in plant metabolism. The investigation showed that the potassium deficiency, accumulation of free nitrogen in leaves is higher (Beegle, 2004). If Zinc deficiency, conversion of nitrogen into protein compounds is reduced and amino acids and amides accumulate in plant (Khurana and Chatterjee, 2008). The main effect of zinc is on the P uptake of the seed that this issue is due to reducing insoluble or low-soluble compounds of phosphorus (Fixen, 2010). Daniel *et al.* (2008) reported that Zinc deficiency in the soil cause that was reduced yield and efficiency of nitrogen, phosphorus and potassium respectively. The studies of Denmead and Shaw (1992) showed that water deficit stress during pollination stage, in the later stages of vegetative growth and in the stage of ear growth reduced the seed yield by 50, 25 and 21 percent respectively (Song and Dia, 2006). For foliar applications, powdered zinc sulfate can be dissolved in water and applied to the leaf tissue. The amount dissolved should supply 0.5 to 1.0 lb. Zn per acre when a rate of 20 gallons of water per acre is used. A zinc chelate can also be mixed with water. The amount of chelate mixed with water should supply 0.15 lb. Zn per acre when water is sprayed at a rate of 20 gallons per acre. Kaya and Higgs (2002) evaluated the response of tomato (*Lycopersicon esculentum* L.) cultivars to foliar application of zinc when grown in sand culture at low zinc. Foliar treatments entailed applying zinc as either 0, 0.35 or 3.5 0.15 $\mu mol.l^{-1}$ $ZnSO_4 \cdot 7H_2O$ to the tops of plants grown at low zinc (0.15 $\mu mol.l^{-1}$) in nutrient solution twice a week during the course of the experiment. Plants treated with 0.15 0.15 $\mu mol.l^{-1}$ Zn in the nutrient solution and high levels of zinc (3.5 $mmol.l^{-1}$) applied as a foliar spray showed a significant decrease in the production of dry matter, chlorophyll and green fruit yield as compared with those grown both at 7.70 $\mu mol.l^{-1}$ Zinc in the nutrient solution and at 0.15 0.15 $\mu mol.l^{-1}$ Zinc in nutrient solution with 3.5 $mmol.l^{-1}$ Zinc applied as a foliar spray. There were differences between the cultivars but no consistent link between these differences and nutrient concentrations within the plant. It seems that placing fertilizer in the non-irrigated furrow of an alternate-furrow irrigation system or placing fertilizer in the row with either alternator every-furrow irrigation has the potential to decrease fertilizer leaching and nutrient elements poisoning without reducing crop productivity (Kajdi and Pocsia, 2003). The objective of the present study was to evaluate the response of maize growth; yield and quality parameters to different irrigation regime and nutrient supply with a view to reduce irrigation applied and extend farming lands with a minimum of yield loss.

## MATERIALS AND METHODS

### *Field and Treatment Information*

New irrigation methods under different nutritional element supplies for maize production was designed and tested for evaluate quantitative and qualitative parameters by split-plot arrangement according complete randomized block design with three replications. This study was conducted under various irrigation strategies and fertilizer combinations with the corn hybrid KSC704. Different Irrigation regimes was belonged to main plots (Conventional furrow irrigation: CFI or $A_1$, Alternate furrow irrigation: AFI or $A_2$ and fixed furrow irrigation: FFI or $A_3$). AFI means that one of the two neighboring furrows was alternately irrigated during consecutive watering. FFI means that irrigation was fixed to one of the two neighboring furrows. CFI was the conventional way where every furrow was irrigated during each watering. Each irrigation method was further divided into five sub-treatments with different fertilizer combinations consisted ($B_1$): Nitrogen + Phosphorus + or N + P as Control, ($B_2$): Nitrogen + Phosphorus + Potassium or N + P + K, ($B_3$): Nitrogen + Phosphorus + Potassium + Zinc or N + P + K + Zn, ($B_4$): Nitrogen + Phosphorus + Potassium + Zinc + Boron or N + P + K + Zn + B and ($B_5$): Nitrogen + Phosphorus + Potassium + Zinc + Boron + Iron or N + P + K + Zn + B + Fe.

### *Farm Management*

One third of nitrogenous fertilizer was used at sowing and the remaining was used at the beginning of germination. Required Fe was extracted from iron sequestering fertilization source (13% Fe) whereas Zn and B were extracted from their commercial resource and according to advices of laboratory, The Zn, Fe and B micro-fertilizers with 4000, 8000 and 6000 ppm condensations concentrations respectively were used through three stages and the beginning of implantation.

### *Measured Traits*

Before harvesting, yield components such as the number of seeds and 1000 seed weight in each row were recorded. Seed yield was calculated in each split-plot after seed moisture reached 14% and the weight of each seed was determined after counting and finally the harvest index was calculated by ratio of seed yield to total above ground biomass. Within each plot, an area of 4 $m^2$ was hand harvested to determine seed yield, leaf area index and total above ground biomass. Dry weights were recorded after the plant material had been oven-dried at 70°C for 48 h.

**Equ. 1.** Ii/Io=e-kl

The extinction coefficient (k) was calculated by the received daily light by canopy surface (lo) and latitude according to Nassiri Mahalaty and Kropft (1997). The extinction coefficient (K) was calculated by the following equation Based on Floyed *et al.* (2007). Light use efficiency calculated from the slope of the regression line between cumulative dry matter and light were calculated with Excel software (Nassiri Mahalaty and Kroph, 1997). LAI (leaf area index): After separating the leaves, the leaves area was measured immediately in the samples by using the portable LAI meter, model IM-300. To measuring nutrient concentrations of nitrogen, phosphorus and potassium on seed was used from Wet digestion method. Uptake of nitrogen, phosphorus and potassium was calculated by multiplying the concentration of the element in the seed on seed yield.

### *Statistical Analysis*

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

## RESULTS AND DISCUSSION

Results of ANOVA showed interaction effects of different irrigation regime and fertilizer combinations on traits of N, P, K Concentrations, N Uptake, P Uptake, K Uptake, Number of seeds per row, 1000 seeds weight, Leaf area index, Radiation use efficiency, Seed yield, biological yield, Number of seeds per row, was significant at 5% probability level (Table 1, 3).

**Nitrogen (N) concentration and its uptake in the seed**

Results of analysis of variance showed that the interaction effects of different irrigation regime and fertilizer combinations on Nitrogen concentration and N uptake in the seed was significant at 5% probability level (Table 1). The highest and lowest concentration of nitrogen and N uptake were obtained that the treatments of alternate furrow irrigation (CFI) and combinations (C + K, Zn, B, Fe) ($A_1$*$B_5$) and CFI *C + K + Zn + B ($A_1$*$B_4$) with (1.68 %) and (217.56 kg.ha$^{-1}$) and the alternate irrigation of fixed and control ($A_3B_1$) with (1.42 percent and 113.62 kg.ha$^{-1}$), respectively (Table 2). Many researchers have been reported that Zn is increasing N uptake in plants. The reason of increasing N uptake is considered because of increasing the dry weight of aerial components (Gupta and Singh, 2005). Foliar application of Zn and Mn increased concentration of these two elements in seed (Movahhedy-Dehnavy *et al.*, 2009).

**Table 1.** ANOVA result of biochemical parameters

| SOV | df | N Concentration | P Concentration | K Concentration | N Uptake | P Uptake | K Uptake |
|---|---|---|---|---|---|---|---|
| **Replication** | 2 | 6.41$^{ns}$ | 0.31$^{ns}$ | 3.46$^{ns}$ | 1.877$^{ns}$ | 13.249$^{ns}$ | 30.805$^{ns}$ |
| **Irrigation (I)** | 2 | 188.8$^{**}$ | 1.61$^{*}$ | 4.25$^{**}$ | 1.49$^{**}$ | 0.0007$^{*}$ | 0.135$^{*}$ |
| **Error (a)** | 4 | 2.01 | 0.24 | 0.05 | 0.001 | 0.0001 | 0.015 |
| **Fertilizer (F)** | 4 | 7.29$^{*}$ | 3.81$^{*}$ | 0.78$^{*}$ | 0.16$^{*}$ | 0.0052$^{*}$ | 0.061$^{*}$ |
| **I×F** | 8 | 201.4$^{**}$ | 39.25$^{**}$ | 28.45$^{**}$ | 2.25$^{**}$ | 0.145$^{**}$ | 18.45$^{**}$ |
| **Error (b)** | 24 | 1.24 | 0.49 | 0.11 | 0.0021 | 0.0008 | 0.009 |
| **CV (%)** | - | 6.32 | 5.25 | 6.09 | 8.41 | 9.23 | 7.89 |

$^{ns}$, * and ** are non-significant and significant at 5% and 1% probability levels, respectively.

**Phosphorus (P) concentration and its uptake in seed**

Results of analysis of variance showed that the interaction effect of different irrigation regime and fertilizer combinations on the concentration of phosphorus and its uptake was significant at 1% probability level (Table 1). Mean comparison result indicated the highest and lowest amount were obtained from the treatments of conventional irrigation and fertilizer (C + K, Zn, B) with 0.34 percent and alternate irrigation or fixed and control ($A_3$*$B_1$) with 0.22 percent respectively. The highest and lowest rate of P uptake in seed with 42.73 kg.ha$^{-1}$ and 17.6 kg.ha$^{-1}$ were obtained from the levels of conventional irrigation and fertilizer treatments (C + K, Zn, B, Fe) and alternate irrigation of fixed and control ($A_3$*$B_1$), respectively (Table 2). There is a positive interaction between zinc and phosphorus that the use of boron increases this trend. In this case the amount of P uptake in the seed and the yield increase that is consistent with the results of this research. Bacon *et al.* (2007) which result to decreased growth and development or death of plant. It has also been well documented that water content and other mineral levels were all positively correlated with organic nitrogen level (Janssen, 1993). The results of the present investigation on increased Fe, phosphorus and nitrogen levels in relation to water deficit samples confirm this report. Jupp and Newman (1987) reported an increase in phosphorus uptake by plant during mild drought. The results obtained on the significant increase in phosphorus level of water deficit samples (WOC) confirm the earlier report of Jupp and Newman (1987).

**Table 2.** The Mean comparison of interaction effect of different irrigation regime and fertilizer combinations on biochemical parameters

| Treatments | N Concentration (%) | P Concentration (%) | K Concentration (%) | N Uptake ($kg.ha^{-1}$) | P Uptake ($kg.ha^{-1}$) | K Uptake ($kg.ha^{-1}$) |
|---|---|---|---|---|---|---|
| **CFI *C ($A_1$*$B_1$)** | 1.55 *bc | 0.27 bc | 0.29 d | 146.47 de | 25.51 cde | 27.4 f |
| **CFI *C+K ($A_1$*$B_2$)** | 1.59 b | 0.29 b | 0.37 bc | 163.45 cd | 29.8 bc | 38.03 d |
| **CFI *C+K+Zn ($A_1$*$B_3$)** | 1.64 ab | 0.32 a | 0.41 ab | 177.12 bc | 34.56 b | 44.3 c |
| **CFI *C+K+Zn+B ($A_1$*$B_4$)** | 1.68 a | 0.34 a | 0.43 a | 206.64 a | 41.82 a | 52.9 ab |
| **CFI*C+K+Zn+B+Fe($A_1$*$B_5$)** | 1.68 a | 0.33 a | 0.43 a | 217.56 a | 42.73 a | 55.7 a |
| **AFI*C ($A_2$*$B_1$)** | 1.52 bc | 0.25 cd | 0.23 ef | 141.97 de | 23.35 de | 21.5 fg |
| **AFI*C+K ($A_2$*$B_2$)** | 1.57 b | 0.26 c | 0.28 de | 160.6 cd | 26.6 cde | 28.6 ef |
| **AFI*C+K+Zn ($A_2$*$B_3$)** | 1.6 ab | 0.28 bc | 0.34 c | 169.9 c | 29.73 c | 36.1 d |
| **AFI*C+K+Zn+B ($A_2$*$B_4$)** | 1.63 ab | 0.32 a | 0.37 bc | 196.58 ab | 38.6 ab | 44.6 c |
| **AFI*C+K+Zn+B+Fe($A_2$*$B_5$)** | 1.64 ab | 0.32 a | 0.38 b | 204.5 a | 39.9 a | 47.4 bc |
| **FFI*C ($A_3$*$B_1$)** | 1.42 c | 0.22 d | 0.2 f | 113.62 e | 17.6 e | 16 g |
| **FFI*C+K ($A_3$*$B_2$)** | 1.47 c | 0.24 cd | 0.25 e | 123.58 e | 20.17 e | 20.17 g |
| **FFI*C+K+Zn ($A_3$*$B_3$)** | 1.52 bc | 0.26 c | 0.28 de | 133.4 e | 23.12 de | 24.9 fg |
| **FFI*C+K+Zn+B ($A_3$*$B_4$)** | 1.52 bc | 0.28 bc | 0.33 c | 147.6 de | 27.19 cde | 32 def |
| **FFI*C+K+Zn+B+Fe($A_3$*$B_5$)** | 1.52 bc | 0.28 bc | 0.33 c | 156.1 cd | 28.75 c | 33.9 de |

CFI ($A_1$), AFI ($A_2$) and FFI ($A_3$): conventional furrow irrigation, alternate furrow irrigation and fixed furrow irrigation, respectively.

($B_1$): Nitrogen + Phosphorus + or N + P as Control, ($B_2$): Nitrogen + Phosphorus + Potassium or N + P + K, ($B_3$): Nitrogen + Phosphorus + Potassium + Zinc or N + P + K + Zn, ($B_4$): Nitrogen + Phosphorus + Potassium + Zinc + Boron or N + P + K + Zn + B and ($B_5$): Nitrogen + Phosphorus + Potassium + Zinc + Boron + Iron or N + P + K + Zn + B + Fe.

*Similar letters in each column show non-significant difference at 5% probability level in Duncan's multiple rang test.

## Potassium (K) Concentration and its uptake in the seed

Results of analysis of variance showed that the interaction effect of different irrigation regime and fertilizer combinations on the concentration of potassium and its uptake was significant at 1% probability level (Table 1). Mean comparison result showed the highest and the lowest amount achieved from treatments of conventional irrigation and fertilizer treatment (C + K, Zn, B) and (C + K, Zn, B, Fe) with 0.43 percent and alternate irrigation or fixed and control ($A_3B_1$) with 0.2 percent respectively. The highest and lowest rates of K uptake in seed with 55.7 $kg.ha^{-1}$ and 16 $kg.ha^{-1}$ were obtained from the levels of conventional irrigation and fertilizer treatments (C + K, Zn, B, Fe) and alternate irrigation of fixed and control ($A_3B_1$), respectively (Table 2). The Zn effect on increasing the concentration of potassium in the seed has been reported by other researchers including (Daniel *et al.*, 2008; Fixen, 2005). But Karimiyan (1995) observed that increasing the Zn concentration in wheat seed, K concentrations in the seed is decreased but N and P concentrations in seed is increased. But in this study by the use of zinc, K concentration has not decreased that is inconsistent with the result of Karimiyan (1995). The uptake of K, N and P by water deficit plants showed their relevance and significance in plant growth and development (survival). It is well established that K is involved in the formation of enzymes, and nitrogen fixation.

## The number of seed per row

Results of analysis of variance indicated that the interaction effect of different irrigation regime and fertilizer combinations on the number of seed per row was significant at 1% probability level (Table 3). Mean comparison result showed that the treatment of conventional irrigation and fertilizer levels (C + K, Zn, B, Fe) with 36.8 had the highest number of seeds in the row and the lowest amount was obtained from the alternate irrigation of fixed and control fertilizer treatment with 21.1 number (Table 4). Water shortage causes the delay in appearance of silk (Tandon, 2005) and reduction of Zn uptake and nutrient, specially the drought stress at flowering stage prevent from the emergence of primary cells of flower and affect the number of seed per ear (Lauer, 2003) that it is quite evident in this study.

**Table 3.** ANOVA result of seed yield, its components leaf area index and radiation use efficiency

| S.O.V | df | No. of seed per row | 1000-Seed weight | Biological yield | Seed yield | Leaf area index | Radiation use efficiency |
|---|---|---|---|---|---|---|---|
| **Replication** | 2 | $69.21^{ns}$ | $1201.49^{ns}$ | $368541.55^{ns}$ | $589882.0^{ns}$ | $0.375^{ns}$ | $0.039^{ns}$ |
| **Irrigation (I)** | 2 | $29.88^{**}$ | $24815.47^{**}$ | $1897921.35^{**}$ | $21582314.21^{**}$ | $5.893^{*}$ | $0.354^{*}$ |
| **Error (a)** | 4 | 0.559 | 525.44 | 525.0 | 374249.44 | 1.525 | 0.051 |
| **Fertilizer (F)** | 4 | $135.42^{**}$ | $21423.71^{**}$ | $1241392.26^{**}$ | $6579938.11^{**}$ | $29.354^{**}$ | $0.128^{**}$ |
| **I×F** | 8 | $75.42^{**}$ | $27001.47^{**}$ | $998841.35^{**}$ | $33414111.39^{**}$ | $17.421^{**}$ | $0.268^{**}$ |
| **Error (b)** | 24 | 0.529 | 1589.51 | 989.3 | 253928.21 | 0.980 | 0.020 |
| **CV (%)** | - | 10.28 | 8.45 | 16.36 | 15.89 | 6.12 | 7.80 |

$^{ns}$, * and ** are non-significant and significant at 5% and 1% probability levels, respectively.

## Thousand seed weight

Results of analysis of variance revealed that the interaction effect of different irrigation regime and fertilizer combinations on the thousand seed weight was significant at 1% probability level (Table 3). Mean comparison result showed that the highest and the lowest amount achieved from treatments of conventional irrigation and fertilizer treatment (C + K, Zn, B, Fe), with average of 382 gr had no significant difference with the alternate irrigation of rotational and fertilizer treatment (C + K, Zn, B, Fe) and alternate irrigation or fixed and control fertilizer treatment with the average 304 gr, respectively (Table 4). Water stress in corn reduces the transfer of photosynthesis materials and prevents from the growth and expansion of the seed (Nelson, 2006) and thousand seed weight is reduced. In this research, the treatment containing macronutrients and three micronutrients obtained the highest rate of thousand seed weight in the condition of low irrigation which is consistent with results of other researchers (Wasson *et al.*, 2009). The water tension in corn, because of leaf water, decreases the photosynthesis and transposition of the materials and excludes the growth of seed (Nelson, 2006) and so the weight of 1000 seeds declines. The inspections declared that the total carbohydrate, starch and protein of seed have increased using Fe and Zn and thus the resistance of plant against the deficit irrigation increase (Marschner, 1995). Deficit irrigation in the regeneration stage of corn leads to the death of granule tube in spike and using some elements such as enough Zn, B and K in the soil leads to lessening this damage and their processes in the soil increase the resistance of plant against the possible damages resulted from deficit irrigation (Lauer, 2003).

## Biological yield

Results of analysis of variance showed that the interaction effect of different irrigation regime and fertilizer combinations on biological yield was significant at 1% probability level (Table 3). Mean comparison result indicated the highest and lowest biologic yield were acquired from conventional irrigations and fertilizer treatment (C + K, Zn, B, Fe) with an average 24920 kg.ha$^{-1}$ which wasn't different from alternate irrigation of rotational and fertilizer treatment (C + K, Zn, B, Fe), fixed and control fertilizer treatment with 18431 kg.ha$^{-1}$, respectively (Table 4).

**Table 4.** The Mean comparison of interaction effect of different irrigation regime and fertilizer combinations on seed yield, its components, leaf area index and radiation use efficiency

| Treatments | No. of seed per row | 1000-Seed weight (gr) | Biological yield (kg.ha$^{-1}$) | Seed yield (kg.ha$^{-1}$) | Leaf area index | Radiation use efficiency (kg.kcal$^{-1}$.m$^{-2}$) |
|---|---|---|---|---|---|---|
| **CFI *C($A_1$*$B_1$)** | 26.3 $^{e}$ | 326 $^{cd}$ | 20485 $^{e}$ | 9450 $^{ef}$ | 3.23 $^{bc}$ | 0.099 $^{d}$ |
| **CFI *C+K($A_1$*$B_2$)** | 28.4 $^{d}$ | 330 $^{c}$ | 21345 $^{d}$ | 10280 $^{d}$ | 3.41 $^{b}$ | 0.108 $^{d}$ |
| **CFI *C+K+Zn($A_1$*$B_3$)** | 30.7 $^{cd}$ | 342 $^{bc}$ | 22420 $^{c}$ | 10800 $^{c}$ | 3.54 $^{ab}$ | 0.118 $^{cd}$ |
| **CFI *C+K+Zn+B($A_1$*$B_4$)** | 34.6 $^{b}$ | 354 $^{b}$ | 23400 $^{b}$ | 12300 $^{b}$ | 3.71 $^{a}$ | 0.140 $^{bc}$ |
| **CFI*C+K+Zn+B+Fe($A_1$*$B_5$)** | 36.8 $^{a}$ | 382 $^{a}$ | 24920 $^{a}$ | 12950 $^{a}$ | 3.86 $^{a}$ | 0.166 $^{ab}$ |
| **AFI*C($A_2$*$B_1$)** | 25 $^{ef}$ | 321 $^{cd}$ | 19936 $^{f}$ | 9340 $^{ef}$ | 2.74 $^{cd}$ | 0.106 $^{d}$ |
| **AFI*C+K($A_2$*$B_2$)** | 27.7 $^{de}$ | 327 $^{cd}$ | 21040 $^{d}$ | 10230 $^{d}$ | 2.87 $^{cd}$ | 0.111$^{d}$ |
| **AFI*C+K+Zn($A_2$*$B_3$)** | 30.2 $^{cd}$ | 340 $^{bc}$ | 22159 $^{c}$ | 10620 $^{c}$ | 2.995 $^{c}$ | 0.127 $^{c}$ |
| **AFI*C+K+Zn+B($A_2$*$B_4$)** | 34 $^{b}$ | 349 $^{bc}$ | 23274 $^{b}$ | 12060 $^{b}$ | 3.14 $^{bc}$ | 0.155 $^{b}$ |
| **AFI*C+K+Zn+B+Fe($A_2$*$B_5$)** | 35.9 $^{ab}$ | 374 $^{a}$ | 24760 $^{a}$ | 12470 $^{a}$ | 3.38 $^{b}$ | 0.175 $^{a}$ |
| **FFI*C($A_3$*$B_1$)** | 21.1 $^{g}$ | 304 $^{d}$ | 18431 $^{h}$ | 8002 $^{g}$ | 2.41 $^{d}$ | 0.108 $^{d}$ |
| **FFI*C+K($A_3$*$B_2$)** | 23.6 $^{f}$ | 312 $^{d}$ | 18972 $^{g}$ | 8407 $^{g}$ | 2.63 $^{d}$ | 0.114 $^{cd}$ |
| **FFI*C+K+Zn($A_3$*$B_3$)** | 26 $^{e}$ | 319 $^{cd}$ | 19530 $^{f}$ | 8894 $^{f}$ | 2.84 $^{cd}$ | 0.130 $^{c}$ |
| **FFI*C+K+Zn+B($A_3$*$B_4$)** | 28.9 $^{d}$ | 327 $^{cd}$ | 20186 $^{e}$ | 9710 $^{e}$ | 2.99$^{c}$ | 0.154 $^{b}$ |
| **FFI*C+K+Zn+B+Fe($A_3$*$B_5$)** | 31.6 $^{c}$ | 334 $^{c}$ | 20729 $^{de}$ | 10270 $^{d}$ | 3.13 $^{bc}$ | 0.163 $^{ab}$ |

CFI ($A_1$), AFI ($A_2$) and FFI ($A_3$): conventional furrow irrigation, alternate furrow irrigation and fixed furrow irrigation, respectively. ($B_1$): Nitrogen + Phosphorus + or N + P as Control, ($B_2$): Nitrogen + Phosphorus + Potassium or N + P + K, ($B_3$): Nitrogen + Phosphorus + Potassium + Zinc or N + P + K + Zn, ($B_4$): Nitrogen + Phosphorus + Potassium + Zinc + Boron or N + P + K + Zn + B and ($B_5$): Nitrogen + Phosphorus + Potassium + Zinc + Boron + Iron or N + P + K + Zn + B + Fe.

*Similar letters in each column show non-significant difference at 5% probability level in Duncan's multiple rang test.

Isarangkura *et al.* (2007) reported the increase of dry matter production in the crop corn by using one kilogram of zinc as solution spray or 10 to 20 kg per hectare of zinc as the land use. They found that dry matter yield of corn is reduced by 50 percent due to stress of Zn deficiency. The results obtained from this study also indicate that the use of potassium and zinc elements can increase the biological yield by 12%. This confirms that Zn solution spray together with the alternate furrow irrigation of fixed and the use of micronutrient fertilizer + Zn foliar spray is increased by 11 percent compared to its similar treatment with fixed irrigation and control fertilizer treatment that shows the effect of Zn element. By taking Zinc, N uptake increase that is due to increasing dry weight of aerial components (Gupta and Singh, 2005). Chimenti *et al.* (2002) which express occurrence of water deficit stress has significant difference on total above ground biomass at end of flowering stage, but microelement Consumption prevented severe reduced total above ground biomass and HI, also this is viewed on seed in row.

## Seed yield

Results of analysis of variance showed that the interaction effect of different irrigation regime and fertilizer combinations on seed yield was significant at 1% probability level (Table 3).

Mean comparison result revealed the treatment of conventional irrigation and fertilizer levels (C + K, Zn, B, Fe), with 12950 $kg.ha^{-1}$ had the highest seed yield that had no significant difference with the treatment of alternate irrigation of rotational and fertilizer treatment (C + K, Zn, B, Fe) and were located at the same statistical group. The lowest amount of yield is also obtained from the treatment of alternate irrigation of fixed and control fertilizer treatment with 8002 $kg.ha^{-1}$ (Table 4) According to Nelson (2006), if low irrigation conditions will be applied in the stages of tasseling and filling and the pasty stage seed yield is decreased by 35.24 and 10 percent, respectively. Fertilizer treatment applied in this study increased the seed yield by 25% that reflects importance of the elements used in increasing the plant tolerance to drought stress. The presence of elements such as zinc, boron and potassium in the soil, in condition of low irrigation, increase the tolerance of corn through different mechanisms (Lauer, 2003). The results obtained here suggest that foliar Zn and Mn application can improve the seed yield and seed quality of the safflower crop grown under drought stress (Movahhedy Dehnavy *et al.*, 2009).

**Leaf area index (LAI)**

Results of analysis of variance indicated that the interaction effect of different irrigation regime and fertilizer combinations on leaf area index was significant at 1% probability level (Table 3). Mean comparison result showed the highest LAI was obtained from two treatments of conventional irrigation and fertilizer treatment (C + K, Zn, B, Fe) with an average of 3.86 that had not significant difference with the treatment of conventional irrigation and fertilizer treatment (C + K, Zn, B) and both were located at the statistical class of a and the lowest amount of LAI was obtained from the treatment of alternate irrigation of fixed and control fertilizer treatment with the average of 2.41 (Table 4). The results obtained in this study showed that low irrigation reduced leaf area that is inconsistent with the results of Boyer (2006); in this study the stress applied from very beginning of vegetative growth that has influenced growth and expansion of the leaf.

**Radiation use efficiency (RUE)**

Results of analysis of variance indicated that the interaction effect of different irrigation regime and fertilizer combinations on radiation use efficiency was significant at 1% probability level (Table 3). Mean comparison result revealed the highest RUE was obtained from the levels of alternate furrow irrigations and fertilizer treatment (C + K, Zn, B, Fe) with an average 0.175 $kg.kcal^{-1}.m^{-2}$ and the lowest amount was obtained from the treatment of conventional irrigation and control fertilizer treatment with an average of 0.099 $kg.kcal^{-1}.m^{-2}$ (Table 4). There is a direct relationship between two elements of LAI and RUE and by increasing LAI per unit area, the extinction coefficient is reduced and URE is increased. In this study, Zn foliar spray together with macronutrient increase the green area of corn plant compared to other treatments and by applying the special methods of irrigation, RUE has significant difference with fertilizer treatment and the triple irrigation that this indicates that effect of zinc on RUE is more than irrigation method applied in this research.

**CONCLUSION**

The highest and lowest of N, P and K uptake, seed yield and LAI were 117.56, 42.73, 55.7 $kg.ha^{-1}$, 12950 $kg.ha^{-1}$ 3.86 and 113.42, 17.4, 16 $kg.ha^{-1}$, 8894 $kg.ha^{-1}$, 2.41 from Alternate furrow irrigation and (C+K, Zn, B, Fe) fertilizer treatment and fixed furrow irrigation and control respectively. The highest of light use efficiency were obtained from Alternate furrow irrigation and conventional furrow irrigation and (C+K, Zn, B, Fe) fertilizer treatment with 0.175 $kg.kcal^{-1}.m^{-2}$. In order to utilize the water sources efficiently and increase corn production under limited water supply, we propose the use of circular irrigation care along with instance, K, Zn, B and Fe fertilizer.

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