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Maize (*Zea mays* L.) Agro-Physiological Response to Potassium and Iron Fertilizer under Water Deficit Stress

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ABSTRACT

This research was conducted to evaluate effect of potassium and iron fertilizers on agro-physiological traits affected different irrigation regime of corn in Shahryar (Tehran province, central of Iran) via a split-split plots arrangement based on randomized complete blocks design with three replications during 2015. The main plot included different irrigation regime (Normal irrigation and stop irrigation at grain filling period). Sub plot consisted different level of K_2O (0, 25, 50 $kg.ha^{-1}$), from water soluble potassium sulfate source. Sub-sub plot included Fe-EDDHA that apply as fertigation 2 $kg.ha^{-1}$, foliar application Fe-EDTA 2 $kg.ha^{-1}$, and no iron fertilizer application as control. Application of Fe-EDDHA as fertigation and Fe-EDTA as foliar application in normal irrigation increased corn seed yield from 5232 $kg.ha^{-1}$ in control to 6622 and 6464 $kg.ha^{-1}$ respectively but in water deficit situation were not effective. In normal irrigation, application 25 and 50 $kg.ha^{-1}$ soluble potassium sulfate increased corn seed yield from 5294 $kg.ha^{-1}$ in control to 6975 and 6048 $kg.ha^{-1}$ respectively. Under water deficit stress application of 25 and 50 $kg.ha^{-1}$ soluble potassium sulfate increased corn seed yield from 3921 $kg.ha^{-1}$ to 4794 and 4807 $kg.ha^{-1}$ respectively. Maximum corn seed yield was achieved when 25 $kg.ha^{-1}$ soluble potassium sulfate and Fe-EDDHA applied together in 6392 $kg.ha^{-1}$. Application soluble potassium sulfate and iron fertilizers increased chlorophyll a, b, and total content in different irrigation regimes. However fertigation of soluble potassium sulfate along with Fe-EDDHA was more efficient to improve chlorophyll a, b, and total and seed yield in water deficit situation.

Key words: *Corn, Fertigation, Foliar application, Seed yield*

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INTRODUCTION

Water is about to become increasingly limited for crop production (Martineau *et al.*, 2017). Maize is the one of the important field crops in creating human food security (Afarinesh, 2015; Shiri *et al.*, 2015). Drought is one of the factors which threaten agriculture products in most parts of the world (Abolhasani and Saeidi, 2004; Banziger *et al.*, 2002). It causes stress in plants and is not only caused by the reduction of rainfalls and great heat, but in the cases where there is moisture in the soil, this moisture cannot be used for plants for some reasons such as excessive soil salinity or soil frost, and plants will be stressed (Baydar and Erbas, 2005). Drought and water shortage are considered an objective reality. In the past, water crisis was not as significant as today, since the population was less, but with the population increase by about six times and the need for more food during the last 100 years, the incidence of this crisis has become more evident than the past (Chimenti *et al.*, 2002). Production of maize for forage or seed requires a lot of water. However in last decades breeders focused on introducing drought tolerant crops (Tabatabaei and Shaleri, 2015) but plant nutrition got a special consideration in water deficit situation (Norastehnia and Farjadi, 2016). Between plant nutrition elements, potassium has a special value in biotic and abiotic stresses like drought stress. Potassium has many physiological role in plants such as enzymes activation in biological compounds synthesis, plant water relationship and stomates opening, photosynthesis and biomaterial transport, induction plant response to biotic and abiotic stresses (Oosterhuit *et al.*, 2013). There have been reports of positive effects of potassium on drought stress (Martineau *et al.*, 2017), salinity stress (Ullah Jan *et al.*, 2017), chilling stress (Karimi, 2017), fungal disease (Zimerman Lax *et al.*, 2018). Research has shown potassium availability in plants under drought stress will increase water absorption by root cells and root extending in soil improve its access to new water and nutrition contents (Grzebisz *et al.*, 2013). This reduces effects of drought stress on plant (Zahoor *et al.*, 2017) and prevents senescence (Lv *et al.*, 2017). Potassium is not only an essential macronutrient for plant growth and development, but also is a primary osmotic in maintaining low water potential of plant tissues. Therefore, for plants growing in drought conditions, accumulating abundant K^+ in their tissues may play an important role in water uptake along a soil–plant gradient. In general, K^+ is accumulated in response to soil water deficits, while Na^+ is accumulated under saline conditions (Glenn *et al.*, 1996). Amalia-Muhd-Zain and Razi-Ismail (2016) reported application potassium in potassium chloride and potassium sulfate forms eliminated water deficit stress on rice growth and development. They emphasized potassium chloride was more effective than potassium sulfate in water deficit elimination. There are some researches that confirm potassium efficacy in subtraction of drought stress in field crop such as safflower (Abedi Baba- Arabi *et al.*, 2012), canola (Fanaei *et al.*, 2011), sesame (Aien, 2012), wheat (Ramezanpour *et al.*, 2009), tobacco (Norastehnia and Farjadi, 2016) and sorghum (Khezerloo *et al.*, 2010). Iron is a micro nutrient element which has especial role in plant photosynthesis. But because of high content of carbonate and bicarbonate in soils from Iran, iron deficiency is obvious in sensitive crops (Martinez-Cuenca *et al.*, 2013). Furthermore water deficit stress complicated the problem. However application of chelated iron fertilizer somewhat solve the problem. Movahhedi Dehnavi and Jalil Sheshbahre (2017) showed that photosystem II of soybean leaves impressed by drought stress and photosynthesis reduced but application of iron and zinc fertilizers retrieved it. Also Ahmadi *et al*. (2016) obtained similar results about iron fertilizer on chick pea photosynthesis under drought stress. Goleg *et al*. (2016) indicated foliar application of ferrous nano oxide one kg.ha^{-1} prevented the effects of drought stress on sesame. Dindoost and Yousefzadeh (2014) found that foliar application of iron fertilizer increased sunflower yield and oil percent under drought stress. Climate change caused long term droughts in some regions of world and agricultural products have been affected extensively. Under water shortage conditions, the effectiveness of fertilizers decreases, especially if consumption of these fertilizers is not compatible with the vegetative growth of plants. However, it should be noted that soils of Iran, which are categorized under the calcareous soils, due to drought stress, salinity, being calcareous, highly acidity, having low contents of organic materials, continuing drought, and continuing unbalanced consumption of fertilizers, iron and potassium contents are too low. Therefore, the plants which grow in such soils are mainly suffered from shortage of iron and potassium and shortage indications are observed in them (Jaleel *et al*., 2009). However water supply for agriculture is getting harder every year but it is possible to produce satisfactory yield with a proper nutrient management under limit water resources. Main goal of research is investigation of potassium and iron fertilizers application on corn physiological properties under water deficit stress.

MATERIALS AND METHODS

Field and Treatment Information

This research was conducted to evaluate effect of potassium and iron fertilizers on agro-physiological traits affected different irrigation regime in Shahryar (Tehran province, central of Iran) via a split split plots arrangement based on randomized complete blocks design with three replications during 2015. Soil texture of research field was sandy loam with pH 7.8. Soil analysis results are shown in table 1. The main plot included different irrigation regime (Normal irrigation and stop irrigation at grain filling period). Sub plot included different level of K_2O (0, 25, 50 kg.ha^{-1}), from water soluble potassium sulfat (Solupotasse, Tessenderlo Group, Belgium) source. Sub-sub plot included Fe-EDDHA [Fe- Ethylene di amine-N, N'-bis (2-hydroxy phenyl acetic acid)] that apply as fertigation 2 kg.ha^{-1}, foliar application Fe-EDTA [Fe Ethylenediaminetetra acetic acid] 2 kg.ha^{-1}, and no iron fertilizer application as control.

Table 1. Result of soil chemical analysis

TNV (%)	12
N (%)	2.66
P_2O_5 (ppm)	0.22
K_2O (ppm)	10
MgO (ppm)	2.8
Fe (ppm)	0.16
Zn (ppm)	0.9

Farm Management

Soil preparation was done with plowing and disking operation. Corn seeds SC704 variety was sown with 75 cm inter row distances with density of 10000 plants per hectare. Experimental plots included four cultured row with 5 m length. The irrigation was carried out at intervals five days and weeds were removed manually.

Potassium sulfate and Fe-EDDHA applied as fertigation and Fe-EDTA applied as foliar in in early corn tasseling stage. Water deficit stress treatment was carried out by stop irrigation in milky seed filling stage of corn.

Measured Traits

Chlorophyll a, b, total and carotenoid were measured in method by Arnon (1967). Leaf samples of corn obtained from nearest leaves to ear in milky seed filling stage. For pigments extract 0.5 g fresh corn leaf crushed in 10 ml acetone 80% solvent then its volume adjusted to 20 ml. The spectrophotometer was calibrated at zero absorption using a blank of pure solvent. Absorbance of samples measured at 645 and 663 nm no longer than 20 minutes after extraction. The equations 1, 2, 3 and 4 were used for chlorophyll and carotenoid calculation:

Equ. 1. Chl.a ($mg.g^{-1}$ FWL) = [12.7 (A_{663})-2.69 (A_{645})] V/1000×W

Equ. 2. Chl.b ($mg.g^{-1}$ FWL) = [22.9 (A_{645})-4.68 (A_{663})] V/1000×W

Equ. 3. Chl.total ($mg.g^{-1}$ FWL) = Chl.a + Chl.b

Equ. 4. Carotenoid = [1000 (A470) – 1.8 (Chl.a) - 85.02 (Chl.b)] × 20

Chl.a: Chlorophyll a, Chl.b: Chlorophyll b, FWL: Fresh weight leaf, A = absorbance at specific wave length, V= final volume of chlorophyll extract in 80 % acetone. W= fresh weight of tissue extract.

At corn harvest, considering the marginal effects, two meter squares of each plot harvested and seed and biological yield measured. Harvest index calculated with equation 5 (Donald and Hamblin, 1976):

Equ. 5. Harvest index = (Seed yield/ Biological yield)*100

Statistical Analysis

Statistical analysis (ANOVA) was applied with using the by the SAS software (Ver.9.1). The differences between treatment means were assessed by least significant difference (LSD) test at 5% probability level.

RESULT

Chlorophyll a

Result of analysis of variance showed that the effect of different levels of irrigation regime, potassium and iron fertilizer and interaction effect of treatments (instead irrigation regime × potassium × iron) on chlorophyll a was significant at 1% probability level (Table 2). Mean comparison result of interaction effect of different level of irrigation regime and potassium fertilizer indicated that maximum chlorophyll a (2.70 $mg.g^{-1}$) was noted for normal irrigation with use 25 $kg.ha^{-1}$ K_2O and minimum of that (1.40 $mg.g^{-1}$) belonged to water stress with non-use potassium fertilizer treatment (Fig.1a). As for LSD classification made with respect to interaction effect of different level of irrigation regime and iron fertilizer maximum and minimum amount of chlorophyll a belonged to normal irrigation with use Fe-EDDHA (2.25 $mg.g^{-1}$) and water stress with non-use iron fertilizer (1.60 $mg.g^{-1}$) (Fig.1b). According mean comparison result of interaction effect of different level of potassium and iron fertilizer maximum amount of chlorophyll a (2.30 $mg.g^{-1}$) was obtained for 25 $kg.ha^{-1}$ K_2O with use Fe-EDDHA and minimum of that (1.38 $mg.g^{-1}$) was for control treatment (Fig.1c).

Chlorophyll b

According result of analysis of variance the effect of different levels of irrigation regime, potassium and iron fertilizer and interaction effect of treatments (instead irrigation regime × potassium × iron) on chlorophyll b was significant at 1% probability level (Table 2).

Evaluation mean comparison interaction effect of different level of irrigation regime and potassium fertilizer revealed the maximum amount of chlorophyll b (1.26 $mg.g^{-1}$) was noted for normal irrigation with use 25 $kg.ha^{-1}$ K_2O and minimum of that (0.48 $mg.g^{-1}$) belonged to water stress with non-use potassium fertilizer treatment (Fig.2a). Assessment result of interaction effect of different level of irrigation regime and iron fertilizer showed the maximum chlorophyll b (1.14 $mg.g^{-1}$) was noted for normal irrigation with use Fe-EDDHA and minimum of that (0.47 $mg.g^{-1}$) belonged to water stress with non-use iron fertilizer (Fig.2b). Evaluation mean comparison result of interaction effect of different level of potassium and iron fertilizer indicated maximum amount of chlorophyll b (1.17 $mg.g^{-1}$) was noted for 25 $kg.ha^{-1}$ K_2O with use Fe-EDDHA and lowest one (0.44 $mg.g^{-1}$) belonged to control treatment (Fig.2c).

Table 2. Result of Analysis of variance of the effect of different level of irrigation regime, potassium and iron fertilizer on measured traits

S.O.V	df	Chlorophyll a	Chlorophyll b	Total chlorophyll	Carotenoid to chlorophyll ratio	Seed yield
Block	2	0.0097^{ns}	0.018^{ns}	0.051^{ns}	0.00027^{ns}	107725^{ns}
Irrigation (I)	1	3.27^{**}	2.17^{**}	10.77^{**}	0.24^{*}	25100698^{**}
Main Error	2	0.018	0.024	0.088	0.0004	184545
Potassium (P)	2	0.59^{**}	0.51^{**}	2.18^{**}	0.0014^{ns}	3846645^{**}
I×P	2	0.41^{**}	0.43^{**}	1.72^{**}	0.00011	2622892^{**}
Sub Plot Error	8	0.026	0.027	0.1	0.00034	108471
Iron (Ir)	2	0.51^{**}	0.37^{**}	1.77^{**}	0.0029^{ns}	3679020^{**}
I × Ir	2	0.29^{**}	0.26^{**}	1.12^{**}	0.00067^{ns}	1770283^{**}
P ×Ir	4	0.16^{**}	0.17^{**}	0.65^{**}	0.00012^{ns}	1045386^{**}
I× P ×Ir	4	0.165^{ns}	0.158^{ns}	0.67^{ns}	0.0012^{ns}	919120^{ns}
Sub Sub Plot Error	24	0.047	0.04	0.17	0.00089	290065
CV (%)	-	11.9	28	16.4	25	9.9

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

Total chlorophyll

According result of analysis of variance the effect of different levels of irrigation regime, potassium and iron fertilizer and interaction effect of treatments (instead irrigation regime × potassium × iron) on total chlorophyll was significant at 1% probability level (Table 2). Assessment mean comparison interaction effect of different level of irrigation regime and potassium fertilizer indicated the maximum rate of total chlorophyll (3.69 $mg.g^{-1}$) was noted for normal irrigation with use 25 $kg.ha^{-1}$ K_2O and lowest one (2.02 $mg.g^{-1}$) belonged to water stress with non-use potassium fertilizer treatment (Fig.3a). Evaluation result of interaction effect of different level of irrigation regime and iron fertilizer revealed the maximum rate of total chlorophyll (3.46 $mg.g^{-1}$) was noted for normal irrigation with use Fe-EDDHA and minimum of that (1.99 $mg.g^{-1}$) belonged to water stress with non-use iron fertilizer (Fig.3b). According mean comparison result of interaction effect of different level of potassium and iron fertilizer the maximum rate of total chlorophyll (3.46 $mg.g^{-1}$) was noted for 25 $kg.ha^{-1}$ K_2O with use Fe-EDDHA and the lowest one (1.90 $mg.g^{-1}$) belonged to the control treatment (Fig.3c).

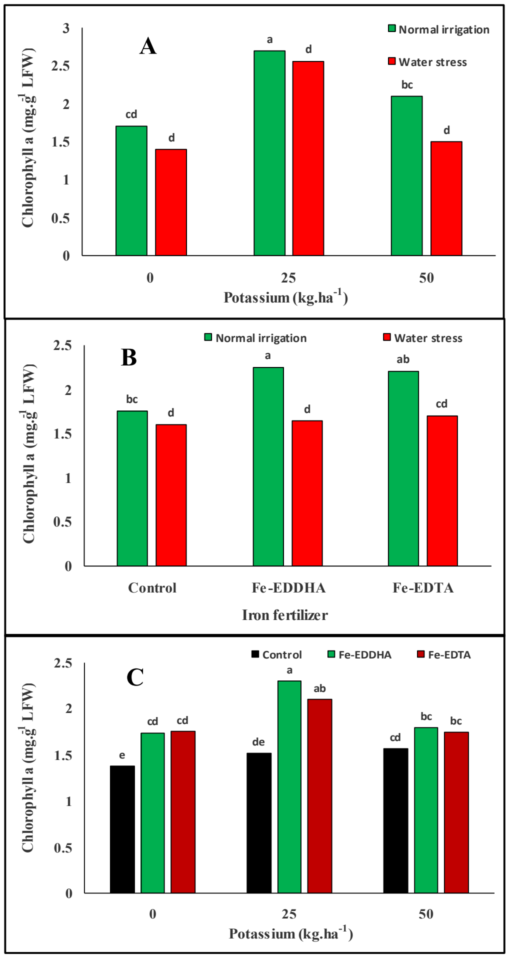

Fig. 1. Mean comparison interaction effect of potassium fertilizer and irrigation regime (A), iron fertilizers and irrigation regime (B), potassium and iron fertilizers iron fertilizer (C) on chlorophyll a concentration via LSD test at 5% probability level.

Carotenoid to chlorophyll ratio

Result of ANOVA showed only effect of different levels of irrigation regime on carotenoid to chlorophyll ratio was significant at 5% probability level (Table 2). Compare different irrigation regime revealed maximum carotenoid to chlorophyll ratio (0.14) was observed in water stress and the lowest one (0.1) was found in normal irrigation (Fig.4).

Seed yield

According result of analysis of variance the effect of different levels of irrigation regime, potassium and iron fertilizer and interaction effect of treatments (instead irrigation regime × potassium × iron) on seed yield was significant at 1% probability level (Table 2). Mean comparison result of interaction effect of different level of irrigation regime and potassium fertilizer indicated that maximum seed yield (6975 $kg.ha^{-1}$) was noted for normal irrigation with use 25 $kg.ha^{-1}$ K_2O and minimum of that (3921 $kg.ha^{-1}$) belonged to water stress with non-use potassium fertilizer treatment (Fig.5a).

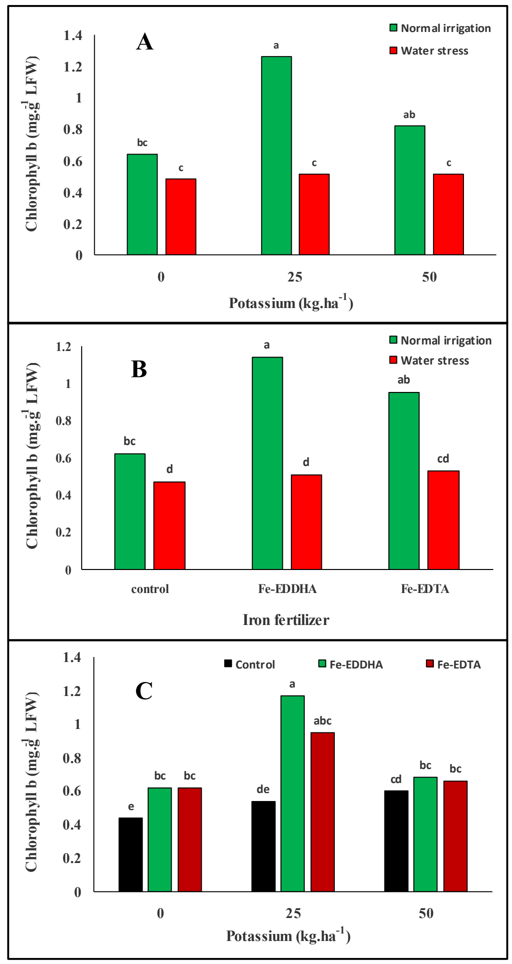

Fig. 2. Mean comparison interaction effect of potassium fertilizer and irrigation regime (A), iron fertilizers and irrigation regime (B), potassium and iron fertilizers iron fertilizer (C) on chlorophyll b concentration via LSD test at 5% probability level.

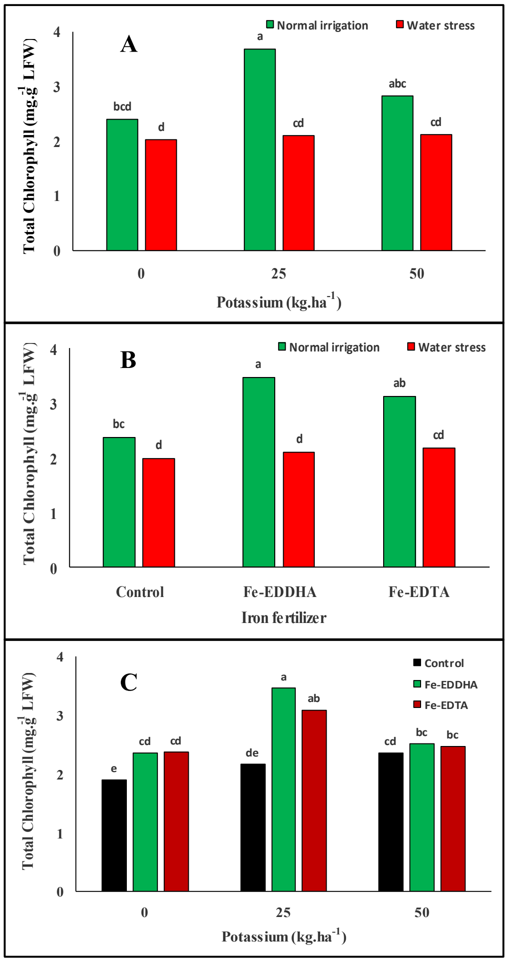

Fig. 3. Mean comparison interaction effect of potassium fertilizer and irrigation regime (A), iron fertilizers and irrigation regime (B), potassium and iron fertilizers iron fertilizer (C) on total chlorophyll concentration via LSD test at 5% probability level.

With respect to interaction effect of different level of irrigation regime and iron fertilizer maximum and minimum seed yield belonged to normal irrigation with use Fe-EDDHA (6622 kg.ha^{-1}) and water stress with non-use iron fertilizer (4572 kg.ha^{-1}) (Fig.5b). According mean comparison result of interaction effect of potassium and iron fertilizer maximum amount of seed yield (6392 kg.ha^{-1}) was obtained for 25 kg.ha^{-1} K_2O with use Fe-EDDHA and minimum of that (4402 kg.ha^{-1}) was for control treatment (Fig.5c).

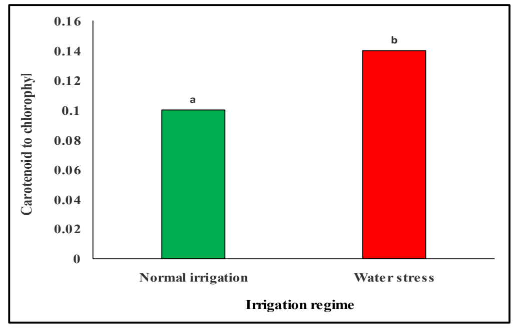

Fig. 4. Mean comparison different level of irrigation regime on carotenoid to chlorophyll via LSD test at 5% probability level.

DISCUSSION

Application of soluble potassium sulfate in normal irrigation significantly increased chlorophyll a, b and total concentration. Total chlorophyll concentration of corn reduced significantly when irrigation stopped in tasseling from 2.36 to 1.99 mg.g^{-1} leaf fresh weight (Fig. 1a, 2a and 3a) like chlorophyll a and b. Application of Fe-EDDHA and Fe-EDTA caused maximum chlorophyll a, b and total concentrations in normal irrigation condition but in water deficit condition there was no significant difference between iron fertilizer application and control treatment (Fig. 1b, 2b and 3b). Maximum total chlorophyll concentration was 3.69 mg.g^{-1} leaf fresh weights when soluble potassium sulfate used in 25 kg.ha^{-1}. In water deficit condition application soluble potassium sulfate changed chlorophyll concentration 2.02 to 2.12 mg.g^{-1} corn leaf fresh weight which there was no significance (Fig. 3a). It was happened for chlorophyll a and b too (Fig. 1a, 2a). As results application of iron fertilizer increased chlorophyll concentration from 1.9 mg.g^{-1} corn leaf fresh weight to 2.36 mg.g^{-1} corn leaf fresh weight in Fe-EDDHA fertigation and 2.37 mg.g^{-1} corn leaf fresh weight in Fe-EDTA foliar application under no soluble potassium sulfate application.

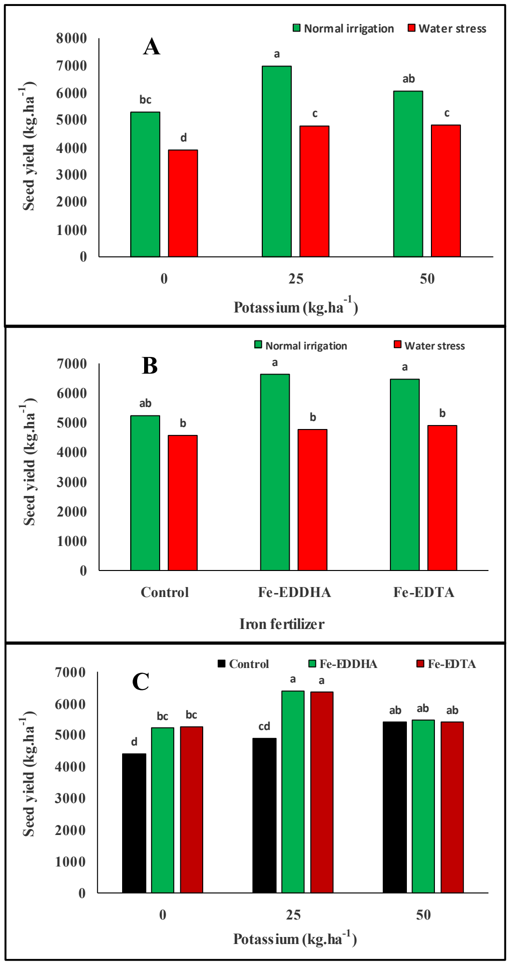

Fig. 5. Mean comparison interaction effect of potassium fertilizer and irrigation regime (A), iron fertilizers and irrigation regime (B), potassium and iron fertilizers iron fertilizer (C) on seed yield concentration via LSD test at 5% probability level.

Application 25 kg.ha^{-1} increased total chlorophyll concentration from 2.17 mg.g^{-1} corn leaf fresh weight to 3.46 mg.g^{-1} corn leaf fresh weight in Fe-EDDHA fertigation and 3.08 mg.g^{-1} corn leaf fresh weight in Fe-EDTA foliar application (Fig. 3c). The similar results obtained for chlorophyll a and b (Fig. 1c, 2c). However potassium and iron fertilizers application increased chlorophyll a, b and total in corn leaves in normal irrigation but in water deficit stress which was interrupted irrigation in corn milky seed filling stage did not changed chlorophyll concentration. Lv *et al.* (2017) showed potassium application after pollination stage increased chlorophyll concentration in wheat. Asgharipour and Heidari (2011) reported sulfate potassium application increased sorghum leaves chlorophyll content. They revealed potassium availability in soil caused drought resistance in sorghum. As shown in Fig. 4, in normal irrigation ratio of carotenoid to chlorophyll was 0.1 but under water deficit situation the ratio of carotenoid to chlorophyll obtained 0.14. It seems that the chlorophyll content of corn leaves is more affected by water deficit stress than carotenoids (Fig. 4). In normal irrigation, application 25 and 50 kg.ha^{-1} soluble potassium sulfate increased corn seed yield from 5294 kg.ha^{-1} in control to 6975 and 6048 kg.ha^{-1} respectively. Under water deficit stress application of 25 and 50 kg.ha^{-1} soluble potassium sulfate increased corn seed yield from 3921 kg.ha^{-1} to 4794 and 4807 kg.ha^{-1} respectively (Fig. 5a). Application of Fe-EDDHA as fertigation and Fe-EDTA as foliar application in normal irrigation increased corn seed yield from 5232 kg.ha^{-1} in control to 6622 and 6464 kg.ha^{-1} respectively but in water deficit situation were not effective (Fig. 5b). Maximum corn seed yield was achieved when 25 kg.ha^{-1} soluble potassium sulfate and Fe-EDDHA applied together in 6392 kg.ha^{-1} (Fig. 5c). In present world water deficiency is one the important problems especially in agriculture. Due to direct effect on root, water deficit stress has influence adversely on nutrient absorption by plant (Wang *et al.*, 2013). However proper nutrition program could reduce negative effects. Premachandra *et al.* (1991) reported availability of potassium increases corn resistance to drought stress because of osmotic balance improvement.

In present study potassium application along with normal irrigation have positive effects on chlorophyll a, b and total content and seed yield of corn. In water deficit situation however potassium application had positive effects on mentioned traits but were not significant. Potassium has important role in transport and metabolism of poly saccharides and amino acids on sink (Hu *et al*., 2018) and sink content is directly concern to cereal seed filling (Lv *et al*., 2017; Arif *et al*., 2017). In other hand potassium is important in opening of stomata and adaptation to surrounding environment (Hasanuzzaman *et al*., 2018) and leaf long life (Lv *et al*., 2017). There are similar reports about potassium important role in cotton (Zahoor *et al*., 2017), rice (Chen *et al*., 2017) corn (Aslam *et al*., 2013), and sunflower (Soleimanzadeh *et al*., 2010). Under normal irrigation in present study application iron fertilizer to both Fe-EDDHA as fertigation and Fe-EDTA as foliar, had positive effects on chlorophyll a, b and total and seed yield of corn. Caliskan *et al*. (2008) revealed application of 400 $gr.ha^{-1}$ Fe-EDTA along with 80 $kg.ha^{-1}$ nitrogen had the best soybean yield. They emphasized application of coated nitrogen fertilizer along with Fe-EDTA as starter increased early plant growth. Janmohammadi *et al*. (2018) reported application of iron and zinc fertilizers along with manure had good results on pea yield. Like this maximum sweet corn seed yield obtained when enriched vermin compost with iron sulfate and zinc sulfate along with foliar application of zinc and iron sulfate applied 20 to 40 days after planting (Arabhanvi and Hulihalli, 2018). In present study however water deficit study reduced corn seed yield but iron fertilizer application somehow compensate the problem. Indeed Heidari *et al*. (2011) indicated application of iron and sulfur fertilizers in water deficit stress affected significantly on iron and nitrogen content and yield of sesame.

CONCLUSION

However water deficit stress is one of the major problems for crop production in present world but it could diminish somewhat by a proper plant nutrition program. As results of present study soluble potassium sulfate application along with Fe-EDDHA in milky seed filling could reduce somewhat effect of water deficit stress on corn.

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