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Application Methods of Iron and Zinc Chelates on Grain Yield and Their Absorption in Maize of Dezful City (Khuzestan Province, South west of Iran)

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RESEARCH ARTICLE

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ABSTRACT

BACKGROUND: Since several decades ago, many attempts have been made to increase crop production. Use of chemical fertilizers is one of these strategies that have increased crop production and fertilizers management is a necessary strategy for achieving sustainable agriculture.

OBJECTIVES: Current study was done to soil application, use in irrigation water, and foliar application of Fe and Zn on grain yield and their absorption in maize of Dezful city.

METHODS: A split plot experiment was conducted with the main factor in randomized complete block design to study various application methods of iron and zinc chelates on SC701 hybrid maize, and the extent of which they can be absorbed by plant in two years. The main plot treatment was fertilizer application methods (FAM) including soil application (SA), foliar application (FA) and use in irrigation water (IW). The subplot treatment was type of fertilizer used (TFU) including iron chelate (IC), zinc chelate (ZC), and control treatments (CT). Traits like plant height, 1000-grain weight, grain yield, number of grains per row, plant iron and zinc contents, and grain protein percentage were measured in the experimental and control treatments.

RESULT: According result of ANOVA for Main factor FAM indicated that there were significant differences only on plant height at a probability level of 99%. For the subplot factor TFU except for grain raw protein content, had significant effects on plant height with probability level of 95% and on 1000-grain weight, grain yield, and plant iron and zinc contents with probability level of 99%. The highest iron content in the plant was obtained in the treatment SA, IC in the first and second year 30.25 and 38 $mg.kg^{-1}$ respectively and the highest amount of zinc, in the SA, ZC in the second year was 33.25 $mg.kg^{-1}$, 1000-grain weight FA, IC was 385 g and grain yield in the treatment of FA, ZC was obtained 5.22 $kg.ha^{-1}$.

CONCLUSION: The highest effect of fertilization was in the treatment FA, ZC amount of 163.33 compared to the control in the second year. The results showed that the addition of iron and zinc fertilizer in the soil due to time consuming, is absorbed at the end of plant growth time, which in turn will not increase the 1000-seed weight and grain yield.

KEYWORDS: *Corn, Foliar application, Soil application, Fertilizer, Nutrition.*

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1. BACKGROUND

Agriculture plays an important role in human food supply. Since several decades ago, many attempts have been made to increase crop production, mainly through making changes in soil conditions so as to satisfy plant needs. Use of chemical fertilizers is one of these strategies that have increased crop production, although their indiscriminate application has caused environmental degradation and pollution (Ju *et al*., 2009; Tilman *et al*., 2001). In most cases, ready-made fertilizer recommendations are used in Iran, and fertilizers are not applied until crop plants show deficiency symptoms. Under these mentioned conditions, yields decline and very low-quality products are produced (Malakouti *et al*., 2008). A high pH level and presence of carbonates and bicarbonates in soils reduce absorption of many nutrients, especially micronutrients like iron and zinc (Sabet and Mortazaeinezhad, 2018). Deficiency of these elements causes health problems for people (Oliver and Gregory, 2015). More than two billion people in Asia, Africa, and Latin America suffer from severe malnutrition and iron (Fe) and zinc (Zn) deficiencies (Grujcic *et al*., 2018; Gupta *et al*., 2008). Playing an important role in many biological processes and as an essential element for plant growth and development as well as human and animal health, zinc enhances root system development, improves nutrient and water absorption, and activates enzymes (Cakmak, 2008; Noulas *et al*., 2018). Due to the low levels of zinc in almost half of the soils worldwide available for plants, the crop yields and quality have declined in cereal cultivation (Noulas *et al*., 2018). Foliar application of Fe and Zn micronutrients on maize increases its forage and grain yield, both of which have a greater positive effect compared to manganese in this respect (Taher *et al*., 2008). Moghadam *et al*. (2015) concluded that for foliar application of various iron chelate concentrations on basil, Fe foliar application at 1g.L was suitable and increased plant length. In a research on iron absorption applied as Fe chelate and siderophores together with Fe chelates by cumin in calcareous soils, it was showed that Fe chelate was effective in increasing cumin yield (Ferreira *et al*., 2019).

2. OBJECTIVES

Considering the importance of micronutrients in improving crop yields for agricultural products, the purpose of this study was compared fertilizer application methods: soil application, use in irrigation water, and foliar application of Fe and Zn to maize, Single-Cross 701 (SC701) variety, in Dezful County, Iran.

3. MATERIALS AND METHODS

3.1. *Site descriptions*

This research carried out at Safiabad Agricultural Research Center, Dezful City, Iran. It is located at 48°32′ E and 32°22′ N and 82m above sea level. It is located 120 km from the center of the province, in the northwest of Khuzestan (Fig. 1).

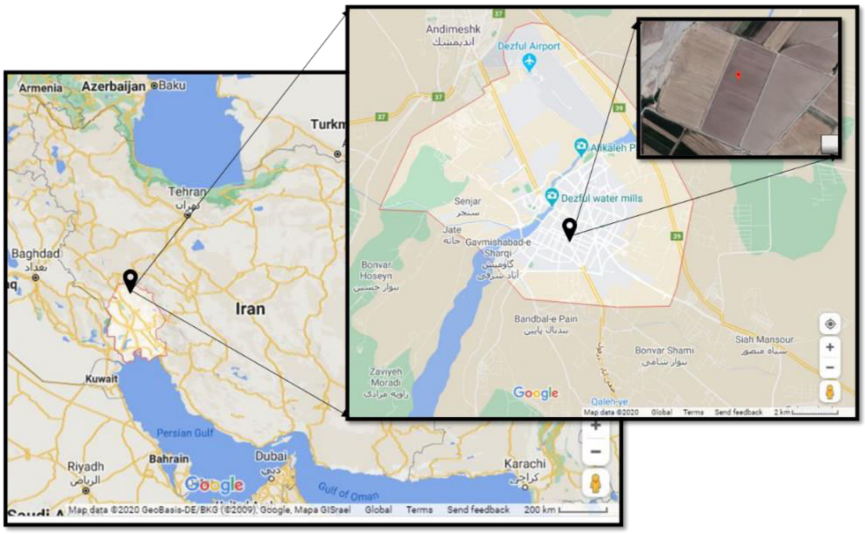

Fig. 1. Location of the study region

The average temperature in winter is 14.9C° and decreases at least sometimes to a few degrees below zero. Which is defined as hyper thermic temperature regime due to high temperature and annual rainfall less than 170 mm. To determine the physical and chemical properties of the soil, five samples were taken from different parts of the soil from a depth of 0-30 cm before the experiment and were analyzed in the soil laboratory of the Research Center. Electrical conductivity of the water and the soil were 0.635 and 4.01 dS.m, respectively. In terms of pH level, the soil was slightly alkaline, its texture was silty clay, and its iron and zinc contents were 0.6 and 1.2 $mg.kg^{-1}$, respectively (Table 1).

3.2. *Experiment plot*

A split plot experiment with the main factor using completely randomized block (three main factors and three subfactors) with four replications was carried out at Safiabad Agricultural Research Center, Dezful City, Iran. There were 36 experimental plots ($4\times 3\times 3m^3$) in this research. Each main plot contained 12 rows and each subplot had four rows with row spacing of 75cm. The length of each subplot was 6m and its width 3m.

Table 1. Soil and water characteristics of the study region

Item	Water	Soil
EC ($dS.m^{-1}$)	0.63	4.01
pH	7.62	7.50
O.C (%)	-	1.00
Mn ($mg.kg^{-1}$)	-	4.80
Cu ($mg.kg^{-1}$)	-	1.40
Fe ($mg.kg^{-1}$)	-	6.00
Zn ($mg.kg^{-1}$)	-	1.20
Texture	-	SiCL

pH, Soil: water = 1:2.5 (w/v); soil moisture, weight after drying at 105°C for 24 h.

The main plot treatment was fertilizer application methods (FAM) including soil application (SA), foliar application (FA) and use in irrigation water (IW). The subplot treatment was type of fertilizer used (TFU) including iron chelate (IC), zinc chelate (ZC), and control treatments (CT). Traits like plant height, 1000-grain weight, grain yield, number of grains per row, plant iron and zinc contents, and grain protein percentage were measured in the experimental and control treatments.

3.3. *Use of Fe and Zn chelates*

The utilized Fe and Zn microelements from their chelate were applied in two phases per treatment as follows: Soil application treatment: The first phase was applied 50g before the first irrigation period at land preparation and 12.5g applied for each furrow and ridge. The second phase: 50g applied at crust breaking operation and 12.5g applied for each ridge and furrow (a total of 200g). Use in irrigation water treatment: The first phase was applied at the 8-leaf stage and the second one at the time of complete appearance of plant organs. 50 g was applied at each phase. 12.5g in 5L of water was used for each ridge and furrow for the fertilizer to be uniformly applied (a total of 200g). Foliar application treatment: The first phase was applied at the 8-leaf stage and second one at complete appearance of plant organs (Khalilvand Behrouziar and Yarnia, 2017). 50g was applied for each phase (a total of 200g at 3 per thousand).

3.4. Measurements of the traits

To measure the traits, by harvesting two planted rows each with a length of 6m from the middle of each plot, five plants were selected per plot, once the grains reached the stage of physiological maturity. The first meter at the beginning and end of each row was omitted to eliminate the border effect. Afterwards, the traits including the number of grains per row, number of rows per cob, number of grains per cob, the 1000-grain weight, grain yield, grain protein percentage, and concentrations of the micronutrients in the experimental and control treatments, were measured. Fe and Zn were measured using the method introduced by Katyal *et al*. (1984). In this method, o-Phenanthroline which was used for Zn extraction as a reagent from the solution extracted from plant tissue, was measured by reading absorbance values on a spectrophotometer.

3.5. *Statistical Analysis*

ANOVA of the obtained data was performed using SAS, EXCEL was employed for drawing the diagrams, and comparison of the means was carried out by using Duncan's multiple range tests at the probability levels of 95 and 99 percent.

4. RESULT

4.1. *Effect of FAM and TFU on traits maize*

Effects of FAM on quantity and quality traits of SC701 maize showed that the FAM had significant effects only on plant height at a probability level of 99%. Except for grain raw protein content, the type of applied micronutrient had significant effects on plant height with probability level of 95% and on 1000-grain weight, grain yield, and plant iron and zinc contents with probability level of 99% (Table 2).

4.2. *Plant height*

The tallest plants were observed in the second and first year of use in irrigation water of micronutrients with heights of 248.42cm and 248.58 cm, respectively. Comparison of the means revealed that, except for SA, effects of FA and use in irrigation water were significant in the first year at a probability level of 95% (Table 3). Comparison of the effects of fertilizer type on plant height showed that the Zn treatment (ZC) produced the greatest height of 274.92cm in the second year (Table 3). The interaction effects of application method and fertilizer type indicated that applying Fe and Zn through use in irrigation water had the greatest effect on plant height both in the first and in the second year, so that the tallest plants were observed for Zn treatment (IW, ZC) with 280cm in the first year and 275.75cm in the second year (Fig. 2).

Table 2. ANOVA of the measured traits influenced by the first factor (method of application) and the second factor (Fe and Zn) in maize

S.O.V	df	Plant height	1000-grain weight	Grain yield	Fe	Zn	Raw protein Content of maize grain
R	2	301.07 ^{ns}	1906.51 ^{ns}	3.10**	83.07*	52.03*	43.19**
M	2	2089.36**	4950.19 ^{ns}	1.34 ^{ns}	32.49 ^{ns}	4.55 ^{ns}	3.03 ^{ns}
(M) e	6	29.32 ^{ns}	1423.37 ^{ns}	0.76 ^{ns}	28.77 ^{ns}	21.35 ^{ns}	2.08 ^{ns}
B	2	4847.86*	7492.11**	10.97**	197.13**	281.02**	3.83 ^{ns}
M× *B*	4	2147.69 ^{ns}	3495.06*	1.28*	49.42	24.51 ^{ns}	3.82 ^{ns}
R× *B*	6	1644.49 ^{ns}	920.18 ^{ns}	0.57 ^{ns}	18.08 ^{ns}	14.28 ^{ns}	12.82**
(B) e	12	1019.99 ^{ns}	732.75*	0.32**	18.12*	12.76*	1.98**
CV	-	13.63	8.31	15.99	21.17	16.70	13.24

$^{ns, *\ and\ **}$: no significant, significant at 5% and 1% of probability level, respectively.

4.3. *Grain weight*

Comparison of the means showed that in the case of 1000-grain weight, the application methods were not significantly different (Table 3). Comparison of the effects of different fertilizers on 1000-grain weight indicated that in the first year, the Fe treatment recorded the largest weight (346.5g), but the greatest 1000-grain weight in the second year (382.92g) was that of the Zn treatment (Table 3). In the case of interaction effects of application method and fertilizer type, revealed that application of Fe and Zn as use in irrigation water and FA had greater effects on 1000-grain weight in the first year. The heaviest 1000-grain weight in the first year belonged to Fe use in irrigation water (IW, IC) with 363.75g and to Fe foliar application (FA, IC) with 385g in the second year (Fig. 2).

4.5. *Grain yield*

Comparison of the means showed that fertilizer application methods (FAM) had no significant difference regarding effects on grain yield at a probability level of 95%. The highest grain yield was that of foliar spray applied at 3.89 and 4 $kg.ha^{-1}$ in first and second years, respectively (Table 3). The applied micronutrients had significant effects on grain yield (Table 3). Fe use in irrigation water (FA, IC) at 4.82 $kg.ha^{-1}$ and 4.88 $kg.ha^{-1}$ in first and second years, caused the highest increase in yield, respectively (Fig. 2).

4.6. Iron content of maize plants

They ways in which fertilizer can be added in the first year, unlike the second year, had no significant difference (Table 3). Applying fertilizer to the soil has increased the amount of iron found in the plant (Table 3). In the first year, the highest amount of iron found in the plant is associated with the addition of iron in the soil (SA, IC) at 30.25 and 38 ppm, respectively, in the first and second years (Fig. 3).

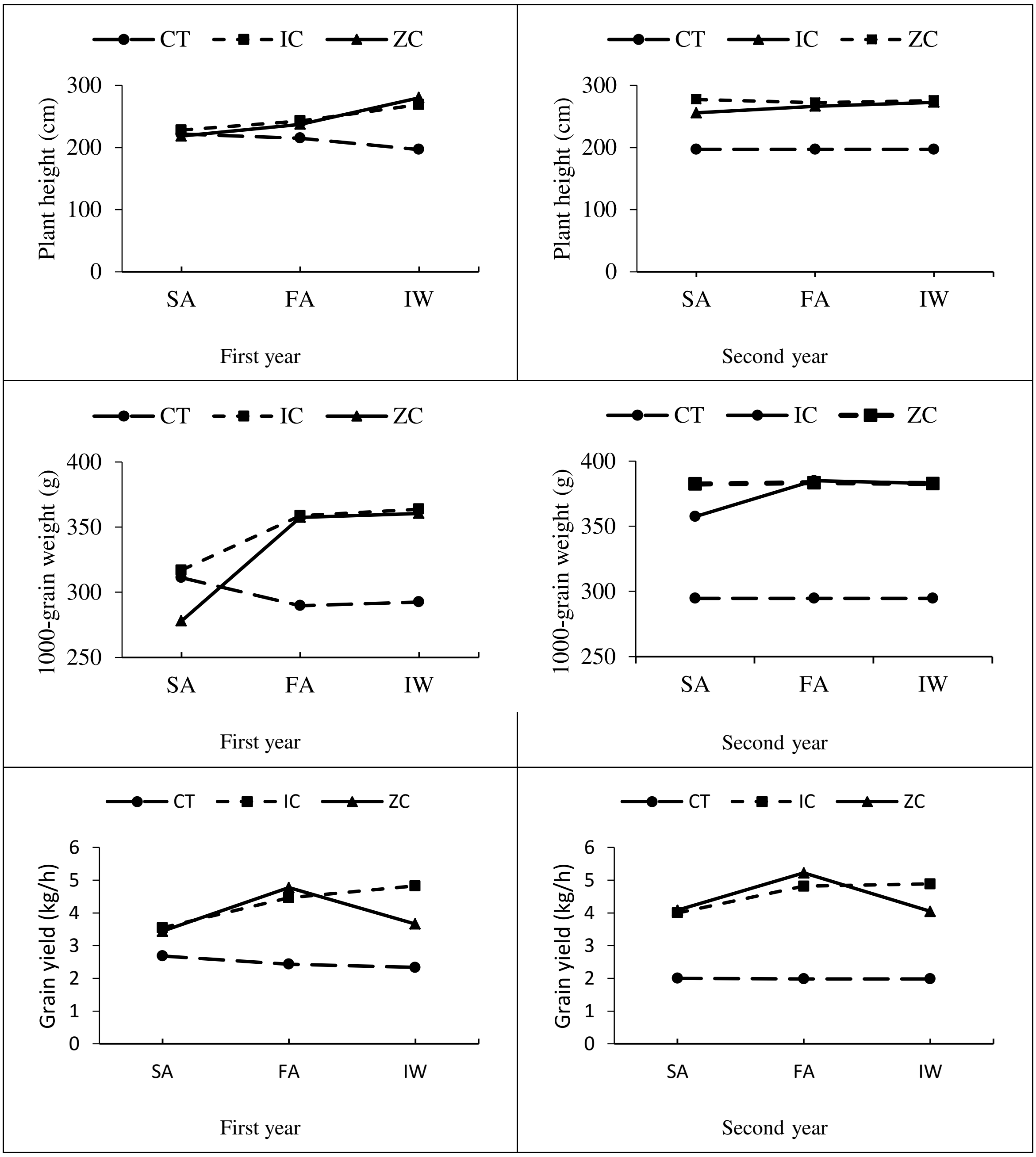

Fig. 2. Interaction effects between FAM and TFU for plant height, 1000-grain weight and grain yield in two years, Soil application (SA), foliar application (FA) irrigation water (IW), iron chelate (IC), zinc chelate (ZC), and control treatment (CT).

4.7. Zinc content of maize plants

Fertilizer applications does not show a significant difference in the zinc content present in plant in the first year (Table 3), but the added fertilizer has a significant difference in the amount of zinc present in the plant (Table 3). The highest zinc content in plant is related to zinc foliar application (FA, ZC) of 28 ppm in the first year and to Soil application (SA, ZC) of 33.25 ppm in the second year (Fig. 3).

Table 3. Effect of fertilizer application methods (FAM) and type of fertilizer used (TFU) on some characteristics of the plant

Year	FAM	Plant height (cm)	1000-grain weight (gr)	Grain yield ($kg.ha^{-1}$)	Fe ($mg.kg^{-1}$)	Zn ($mg.kg^{-1}$)	Grain Protein (%)
First	Soil	222.58 [*c]	302.08 [a]	3.22 [a]	22.00 [a]	22.08 [a]	10.33 [a]
	Foliar	231.67 [b]	335.33 [a]	3.61 [a]	19.01 [a]	21.18 [a]	10.37 [a]
	water	248.58 [a]	338.92 [a]	3.89 [a]	19.33 [a]	20.91 [a]	11.22 [a]
Second	Soil	243.33 [a]	344.92 [a]	3.36 [a]	26.25 [a]	25.83 [a]	11.13 [a]
	Foliar	245.17 [a]	354.42 [a]	4.01 [a]	21.85 [ab]	23.35 [ab]	11.22 [a]
	water	248.42 [a]	353.42 [a]	3.64 [a]	18.90 [b]	21.32 [b]	11.80 [a]
Year	**TFU**	**Plant height (cm)**	**1000-grain weight (gr)**	**Grain yield ($kg.ha^{-1}$)**	**Fe in plant ($mg.kg^{-1}$)**	**Zn in plant ($mg.kg^{-1}$)**	**Grain Protein (%)**
First	Control	211.08 [b]	297.83 [b]	2.49 [b]	15.75 [a]	19.33 [a]	11.22 [a]
	Fe chelate	246.58 [a]	346.50 [a]	4.28 [a]	23.75 [b]	17.92 [a]	10.09 [a]
	Zn chelate	245.17 [a]	332.00 [a]	3.96 [a]	20.83 [b]	26.92 [b]	10.61 [a]
Second	Control	197.00 [c]	294.75 [b]	1.99 [b]	14.50 [c]	18.67 [b]	11.05 [b]
	Fe chelate	265.00 [b]	375.08 [a]	4.57 [a]	28.25 [a]	19.83 [b]	11.61 [ab]
	Zn chelate	274.92 [a]	382.92 [a]	4.45 [a]	24.25 [b]	32.00 [a]	11.83 [a]

*Within a column, means followed by different lowercase letters are significantly different ($P \leq 0.05$)

4.8. *Grain protein percentage*

Fertilization method had no significant difference in protein content in both years. In the second year, zinc increased protein content (Table 3). So that, the highest protein content is associated to zing use in irrigation water treatment (IW, ZC) in the first year by 12.15% (Fig. 3).

5. DISCUSSION

Research has demonstrated that application of Fe fertilizers on saline soils decreases sodium and chlorine concentrations and improves plant growth (Delgado and Sánchez-Raya, 2007; Moghadam *et al*., 2015). Plant chlorophyll cannot be produced without iron, and iron deficiency or inactivity in plants reduces chlorophyll content and hence their growth (Kathpalia and Bhatla, 2018). Plant height is increased by applying iron fertilizer as it improves chlorophyll production in leaves, consequently increasing photosynthesis. Therefore, more photosynthesis products enter various plant organs including stems, allowing the plants to growing taller (Hameed Khan and Krishnakumar, 2018). The greatest 1000-grain weight was achieved by applying Zn and Fe. It is similar to Bybordi and Mamedov (2010) results obtained in colza. Micronutrients increase 1000-grain weight through improving absorption of elements like nitrogen (Mahler and Westermann, 2003). Presence of sufficient amounts of nutrients in plant organs results in better grain filling and increased grain weight. Zinc is necessary in the biosynthesis of growth regulators like indoleacetic acid and carbohydrates that improve yield and yield components. It may be due to their importance in accumulation of assimilates in grains in the final stages of plant growth, and as a result, production of larger and heavier grains.

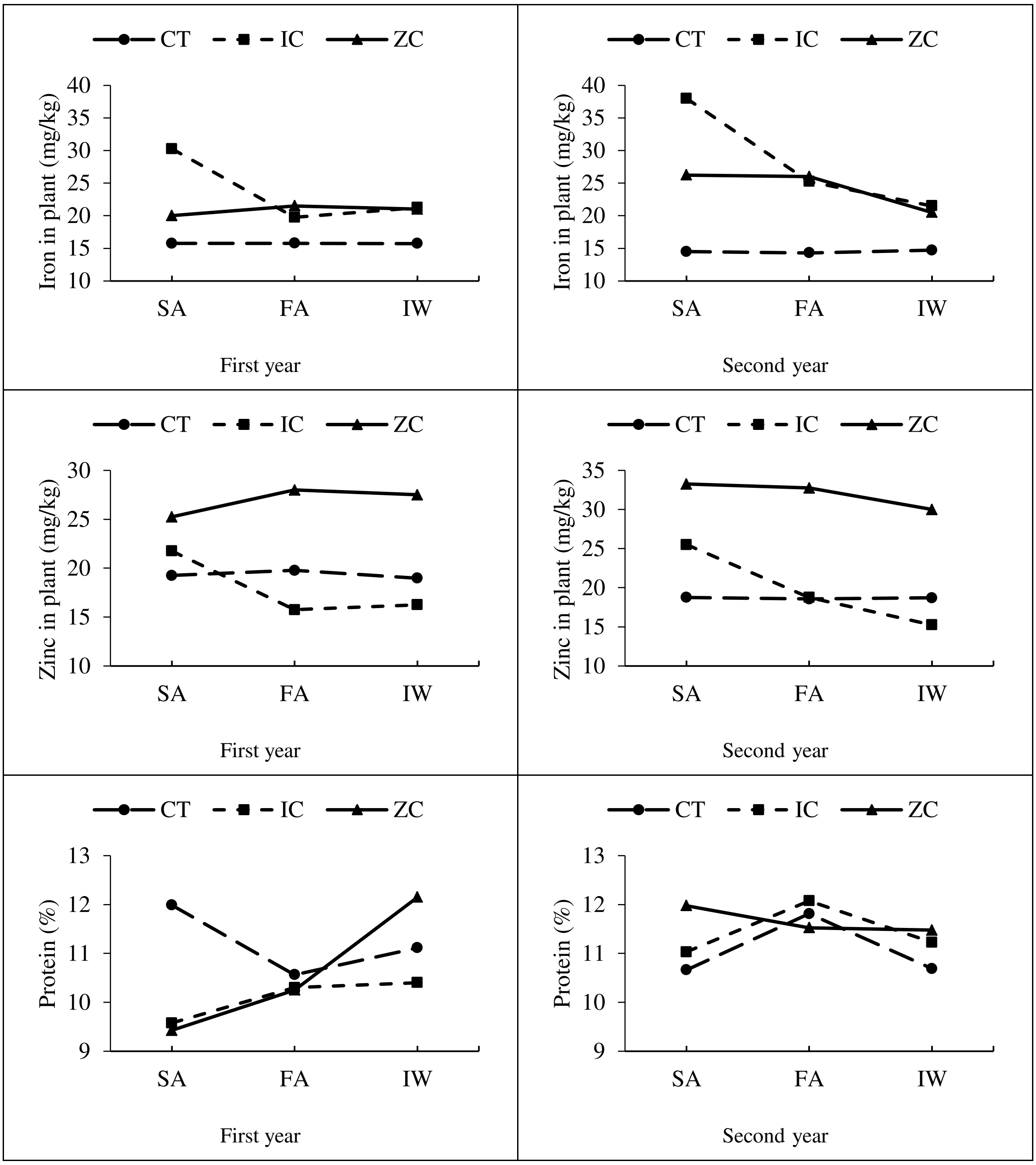

Fig. 3. Interaction effects between FAM and TFU for Iron, Zinc and Protein in two years. Soil application (SA), foliar application (FA) irrigation water (IW), iron chelate (IC), zinc chelate (ZC), and control treatment (CT)

Reduced number of grains per plant under nutrient deficiency indicates the negative effects of absence of the aforementioned micronutrients, consequently preventing the reproductive organs from preparing for grain production (Bybordi and Mamedov, 2010; Xue *et al*., 2003). Application of micronutrients can increase water and nutrient absorption, and greater foliage expansion allows plants to absorb more radiation. These factors increase biomass yield and grain yield (Arnold Bruns and Abbas, 2005). Increased production of assimilates improves storage of materials and hence enhances physiological performance. Reduction in the rate of plant aging, and hence possibility of more photosynthetic activity by plants, are among other reasons for the greater number of grains obtained by applying micronutrients (Bakhtavar *et al*., 2015). The increase of iron content in SA conditions is because of no increase in grain yield, due to the delay in its absorption by plant roots. The amount of iron found in the plant has been measured at the end of the growing season, and its application has been done by use in irrigation water and FA. But in the case of application to the soil, the process of conversion into absorbable form is likely to be long, and is absorbed by the plant at the end of the growing season. One of the major problems of alkaline soils, which forms a large part of the soils of arid and semi-arid regions of Iran, is the iron deficiency for plants (Ksouri *et al*., 2007). Zinc is one of the essential elements in plant nutrition. Among its essential roles of zinc is its contribution to the building of 200 types of enzymes and proteins, and its lack, reduces the activity of several important enzymes including phosphatases, dehydrogenase, dimetidine kinase, carboxy peptidase and polymerase RNA, DNA (Mousavi, 2011). Thalooth *et al*. (2006) indicated that zinc would not significantly increase the protein content of seeds, but Sawan *et al*. (2001) indicated to the positive effect of Zinc on the increase in seed protein. In Fe and Zn chelate application, the largest increase (106.59%) was that of grain yield IW, IC and the largest decrease (21.38%) that of grain raw protein content SA, ZC (Table 4).

5. CONCLUSION

An experiment using the randomized complete block design was conducted to study application methods of the micronutrients zinc and iron for SC701 maize. The results showed that the application of fertigation and FA of iron and zinc fertilizers in comparison to SA has a more effective effect on the measured characteristics of maize. The greatest effect of application of fertilizer was for grain yield, iron, zinc, plant height, 1000-grain weight and raw protein content compared to control, respectively. The highest increase was observed for Fe use in irrigation water treatment. The use of iron and zinc as SA in arid and warm soils of Iran will delay the absorption of the elements and it will not increase the yield. In this condition, use in irrigation water will have a positive effect on grain yield and other characteristics of maize.

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FOOTNOTES

AUTHORS' CONTRIBUTION: All authors are equally involved.

CONFLICT OF INTEREST: Authors declared no conflict of interest.

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