



## Influence of Foliar Application of some Micronutrients on Maize Kernel Yield and Nutrient content.

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### Abstract

The present study was conducted to evaluate the effect of various levels of some micronutrients Zn, Fe and Cu individually and in combination on maize (*Zea mays* L.) kernel yield and kernel content of micronutrients using foliar application. The field experiment was behaved at Qlyasan Agricultural Research Farm in the Sulaimani Governorate of the Kurdistan Region of Iraq from April to August 2019. The experimental treatments laid out in a complete randomized block design (RCBD) with three replicates. The treatments were included three levels of Zn (2, 4 and 6 kg ha<sup>-1</sup>), three levels of Fe (3, 5 and 7 kg ha<sup>-1</sup>) and three levels of Cu (2, 3 and 4 kg ha<sup>-1</sup>) as individual and three levels of combined Zn + Fe + Cu (2 + 3 + 2 kg ha<sup>-1</sup>), Zn + Fe + Cu (4 + 5 + 3 kg ha<sup>-1</sup>) and Zn + Fe + Cu (6 + 7 + 4 kg ha<sup>-1</sup>) with control. The results revealed that the foliar application of some micronutrients significantly affected in kernel yield of maize and the uptake of applied micronutrients by maize kernel at ( $P \leq 0.05$ ). The maximum kernel yield of maize was 12.63 Mg ha<sup>-1</sup> obtained with the application of Zn (2 kg ha<sup>-1</sup>) (T2) along with recommended NPK. Also, the results showed that the foliar feeding affected significantly of micronutrient uptake by the kernel of maize plant, the maximum values of micronutrient uptake by maize kernel for Zn, Fe and Cu were 2.95 kg ha<sup>-1</sup>, 9.25 kg ha<sup>-1</sup> and 4.94 kg ha<sup>-1</sup> from the treatments T12, T12 and T6 respectively.

### Introduction

Maize (*Zea mays* L.) along with rice and wheat is one of the three major food crops in the world and is known as the golden meal due to its high kernel yield and nutritional value [1]. The rise in maize consumption is also due to a renewed interest in traditional dishes and divers maize products [2]. Maize, wheat and rice supplied at least 30% of the food calories to over (4.5 billion) people in ninety-four developing countries [3]. Increased maize production is needed to meet animal feed and biofuel demands [4]. There are many factors that restrict the maize yield but the most deleterious nutrient deficiency [5]. There are very small amounts of micronutrients in both soils and plants but their function is often as important as primary or secondary nutrients [6]. Micronutrients are trace elements that are also required in small quantities by the maize crop and play an active role in the metabolism of the plant, shortages display deficiency symptoms and reduced crop yields [7]. Zinc (Zn), iron (Fe), and copper (Cu) are essential plant and human micronutrients [8]. These micronutrients assist in the formation of chlorophyll, nucleic acid, protein synthesis and play an active role in various enzymatic photosynthesis and respiration activities [9]. Micronutrients also play a key role in the release of carbon dioxide and in the optimization of vitamin A and immune system functions [10]. Zinc is essential in the division of cells, protein synthesis, the immune system and growth [11]. Zinc is essential for the regulation of sugar and enzymes which control plant growth. Formation of some growth hormones, auxin metabolism, the activity of dehydrogenases enzymes, synthesis of cytochrome, etc. is influenced by zinc [12]. Iron is the most abundant element on the earth as a whole and the fourth most plenteous element in the earth's crust [6]. Iron is momentous for photosynthesis, respiration, hydrocarbon production, chloroplast development, and chlorophyll formation and therefore, it is indirectly responsible for much of the green color

of growing plants [13]. Enzymes to regulate transpiration in plants also use iron [14]. It also participates in the oxidation process that releases energy from sugars and starches and in responses that convert nitrate to ammonium in the plant [6]. Copper is documented as an essential micronutrient for normal growth and metabolism of plants [15]. Copper is important for physiological redox processes, pollen viability and lignification [16]. This element plays a role in protein and carbohydrate metabolism as well as enzymatic systems [17]. Copper participates in the formation of chlorophyll and is a part of many enzymes such as cytochrome oxidase. Chlorophyll can contain as much as 70% of the Cu in plants, largely bound to chloroplasts [18].

In a specific form, plants require a specific amount of certain nutrients at the appropriate time for their growth and development [19]. Any stress, nutritional deficiency of these elements, direct and indirect adverse effects on human health and the live animals [20]. It is well documented that micronutrient deficiency (Zn, Fe, and Cu) in arid and semi-arid soils is one of the most critical yield-limiting factors and can greatly drop plant yield and quality [21]. Micronutrient deficiency can either be primarily due to its low total contents, or secondary caused by many factors in soil that reduce plant availability, the contents of available Zn, Fe and Cu were higher in surface horizons and decreased with depth in most of the soil series [22]. These factors include the calcareous nature of soils, high pH, low organic matter, salt stress, continuous drought, high levels of bicarbonate in irrigation water, and imbalanced use of NPK fertilizers [23]. The capacity of the soil to provide these nutrients, nutrient absorption rate to functional sites and mobility of nutrients within the plants. Interaction between the micronutrient and certain macronutrients occurs [24]. Crops under these soil conditions may suffer from a deficiency in micronutrients [25]. Micronutrient solubility in calcareous soils is experimentally low due to its high pH value, which causes lowers nutrient absorption and increases plant demand for such nutrients [26].

Foliar nutrition is a very helpful method to solve this problem when nutrient deficiencies cannot be corrected by nutrient applications to the soil [27]. The foliar application method is generally preferred because very small amounts of fertilizers are applied per unit area and groundwater pollution is reduced [28]. This method of application of nutrients is easy and simple to improve plant nutritional conditions, as stated for maize and wheat [29, 30].

Due to the role of these elements in maize as mentioned before, and the importance of maize among industrial crops, therefore, the aim of this study was to investigate the foliar application effect of some micronutrients (Zn, Fe, and Cu) on kernel yield and nutrients content of maize (*Zea mays* L.) kernel.

## Materials and Methods

### *Experimental design*

The study was conducted during the spring season growing in April 2019 to August 2019 at Qlyasan Agricultural Research Farm with GPS reading of (45° 22' 1" E, 35° 34' 18" N 757m above sea level) in Sulaimani governorate, Kurdistan Region of Iraq. The experiment was laid out in a randomized complete block design (RCBD) using maize (*Zea Mays* L.) hybrid Cultivar (RONALDINIO) with thirteen treatments by three replications and a plot size of 3 m × 1.5 m=4.5m<sup>2</sup>. Each plot had 3 rows, there was a 2m distance between blocks two adjacent plots and the distance between experiment units was 1m. Seeds were sown 5cm deep with two seeds and it was planted manually on 15<sup>th</sup> April 2019. The recommended N, P, and K doses were applied at 200-250-150 kg N: P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O ha<sup>-1</sup> as urea, triple superphosphate, and potassium chloride, respectively. In all treatments, through side dressing at the time of sowing, while N applied in two periods. The first half of N was applied after 21 days from the sowing time and the second half was added at the tasseling time. All the other agronomic practices were kept uniform. The drip system was used for irrigation the crop every 2-3 days based on irrigation scheduling. Weeds were removed manually. The micronutrients were applied by the foliar application after one month from germination. The source of micronutrients used in the experiment ZnSO<sub>4</sub>, FeSO<sub>4</sub>.7H<sub>2</sub>O, and CuSO<sub>4</sub>. The solutions were prepared in distilled water. Three levels of (Zn, Fe, and Cu) as individual treatments and combination treatments with control were used. The detail of treatments is given as follow:

T1= control	T8=Cu (2kg ha <sup>-1</sup> )
T2= Zn (2 kg ha <sup>-1</sup> )	T9= Cu (3 kg ha <sup>-1</sup> )
T3= Zn (4 kg ha <sup>-1</sup> )	T10= Cu (4 kg ha <sup>-1</sup> )
T4= Zn (6 kg ha <sup>-1</sup> )	T11= Zn + Fe + Cu (2 +3 + 2 kg ha <sup>-1</sup> )
T5= Fe (3 kg ha <sup>-1</sup> )	T12= Zn + Fe + Cu (4 + 5 + 3 kg ha <sup>-1</sup> )
T6= Fe (5 kg ha <sup>-1</sup> )	T13= Zn + Fe + Cu (6 + 7 + 4 kg ha <sup>-1</sup> )
T7= Fe (7 kg ha <sup>-1</sup> )	

**Sample collection and physicochemical analysis**

Soil samples were taken from (0 -30 cm) of the soil used in the field experiment and were prepared for some physical and chemical analysis. Soil particle size distribution was determined according to international pipette methods according to the methods described by Black [31]. The real density of soil was determined by the Pycnometer method according to Lal [32]. Soil bulk density is measured by the clod method covering with paraffin wax, as described by Blake and Hartge[33]. Wilting points, field capacity, and available water were determined from the models proposed by Karim [34]. The soil reaction (pH) and electrical conductivity (ECe) were measured for the soil saturation extract with a pH meter (HANA), model (HI 83141) as mentioned by Estefan *et al.* [35], and EC meter, model (Conductivity meter laboratory/portable VARIO® Cond WTW), according to Rhoades [36] respectively. Some cations and anions in the soil saturation extract were determined according to Estefan *et al.* [35]. Sulfate was indirectly determined from combined Ca and Mg by titration with (0.01N) EDTA disodium salt, according to Jackson[37]. Soil organic matter content was determined using the method Walkley and Black [38], as described by Estefan *et al.*[35]. The cation exchange capacity of the soil (CEC) was determined by using an ion-exchange process method with ammonium acetate (NH<sub>4</sub>OAc) pH 8.1 as an extraction solution, according to Estefan *et al.*[35]. Total calcium carbonate (CaCO<sub>3</sub>) in the soil, was determined with 1M HCl, and the excess of HCl was titrated with 1M NaOH by using phenolphthalein indicator Loeppert and Suarez [39]. The active lime or active equivalent CaCO<sub>3</sub> (AECC), which is a fine particle size calcite, was estimated by the 0.2M NH<sub>4</sub>-oxalate method according to Kozhekov and Yakovleva[40]. The available phosphorus concentration was determined by extracting the samples with 0.5M NaHCO<sub>3</sub> as mentioned by Olsen [41]. Total N in soil sample was determined by the Kjeldahl method as described by Estefan *et al.*[35]. Available Zn, Fe, and Cu in the soil before sowing were determined according to the method of Lindsay and Norvell [42]. The soil sample was analyzed before seedling and the result of some physical and chemical properties of the soil samples are presenting in the (Table 1). Plants were grown till maturity, after which cobs were harvested at 112 days after the cobs were shelled; kernel yields were measured and converted into Mg ha<sup>-1</sup> at 15.5% moisture as mentioned by Eteng *et al.*[43]. Kernels were ground and digested using the wet oxidation procedure by digestion kernels with (HNO<sub>3</sub>, HClO<sub>4</sub> and H<sub>2</sub>O<sub>2</sub>) according to Pequerul *et al.*[44]. The concentrations of (Zn, Fe, and Cu) in maize kernels and soil were determined by using Atomic Absorption Spectrometer, Perkin Elmer, A. Analyst 800.

Kernel yield and nutrients uptake in the kernel of maize plant was calculated by the following formula

$$\text{Kernel yield (Mg ha}^{-1}\text{)} = (\text{plant density ha}^{-1}\text{)} \times (\text{kernel yield kg plant}^{-1}\text{/1000)} \dots\dots\dots (1)$$

$$\text{Nutrients uptake by kernel (kg ha}^{-1}\text{)} = \frac{\text{Nutrients content in (kernel \%)} \times \text{kernel yield (kg ha}^{-1}\text{)}}{100} \dots\dots (2)$$

**Statistical analysis of data**

The data were analyzed statistically, using XLSTAT (2016) package and the differences were compared by Duncan Multiple Range Test (DMRT) at the 5% significance level.

## Results and Discussion

### *Some initial Soil characteristics at the trial site*

Some selected physical and chemical characteristics of experimental soil are presented in (Table 1) and the experiment was carried out in silty clay loam soil. The pH value was 7.75 with 230.5 g kg<sup>-1</sup> lime content. The deficiency of micronutrients in plants in calcareous soils is stronger and therefore to reclaim these deficiency problems in soils can be recovered by foliar feeding.

Table-1: Some physicochemical properties of the soil used in the field experiment.

Physical properties of the soil used in the field experiment								
Particle Size Distribution (PSD) g kg <sup>-1</sup>				Real density	Bulk density	Welting point at -1500kPa	Field capacity at -33kPa	Available water
Sand	Silt	Clay	Texture class	kg m <sup>-3</sup>		g kg <sup>-1</sup>		
66.00	549.00	385.00	Si CL*	2493.48	1338.30	180.52	285.72	105.20
Chemical properties of the soil used in the field experiment								
Soluble ions mmol L <sup>-1</sup>								
pH	EC dS m <sup>-1</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	K <sup>+</sup>	Na <sup>+</sup>	SO <sub>4</sub> <sup>2-</sup>	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>
7.75	0.55	2.04	0.35	0.21	0.67	1.22	2.70	1.88
O.M.	Total N	CaCO <sub>3</sub>		Available Zn	Available Fe	Available Cu	CEC	Available P
		Total	Active					
		g kg <sup>-1</sup>		mg kg <sup>-1</sup>		cmol <sub>c</sub> kg <sup>-1</sup>		mg kg <sup>-1</sup>
16.75	1.58	230.50	35.80	4.63	4.73	8.61	46.48	6.19

\* Si CL = Silty Clay Loam.

### *Influence of foliar application of micronutrients on kernel yield of maize*

The data regarding kernel yield of maize which presented in Figure (1), appeared that the foliar feeding significantly influenced the kernel yield (Mg ha<sup>-1</sup>) at (P≤ 0.05). Among various treatments maximum kernel yield mean value was (12.63 Mg ha<sup>-1</sup>), produced by treatment (T2) whereas minimum kernel yield value was (9.75 Mg ha<sup>-1</sup>), and observed in treatment (T10).

These results corresponding with the results found by Zeidan *et al.*[45], who found that the impact of potassium and micronutrients caused an increase in kernel yield of maize plants significantly. Eteng *et al.*[43] also reported that the application of Zn was significantly affected on kernel yield.

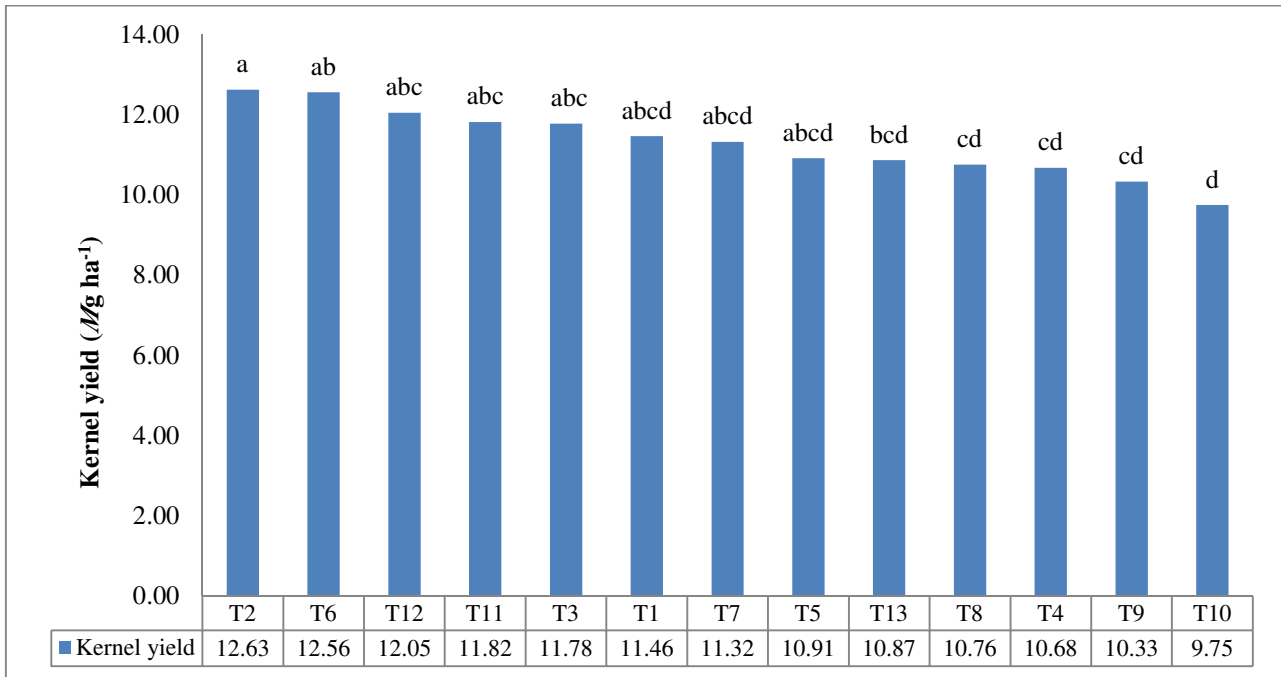


Figure- 1: Influence of foliar application of Zn, Fe, and Cu micronutrients in individual and combined on kernel yield of maize.

***Influence of foliar application of some micronutrients on the concentration of applied micronutrients in the kernel of maize plants:***

***Zinc concentration in maize kernel***

The data in Figure (2), conform that Zn concentration in maize kernel significantly impacted by foliar feeding of studied micronutrients in individual and combination at ( $P \leq 0.05$ ), the maximum mean value of Zn concentration in the kernel was ( $245.50 \text{ mg kg}^{-1}$ ) observed with treatment (T12), while the lowest mean value of Zn concentration in the kernel was ( $133.67 \text{ mg kg}^{-1}$ ) observed with treatment (T2). These results a harmonic with the results found by Johnson *et al.* and Tariq *et al.*[46, 47]. Tariq *et al.*[47] reported that Zn concentration in kernels of maize was significantly increased by the application of  $\text{ZnSO}_4$ . Foliar and soil application of zinc fertilizers seems to be an effective way to increase the concentration of kernel zinc in maize [46].

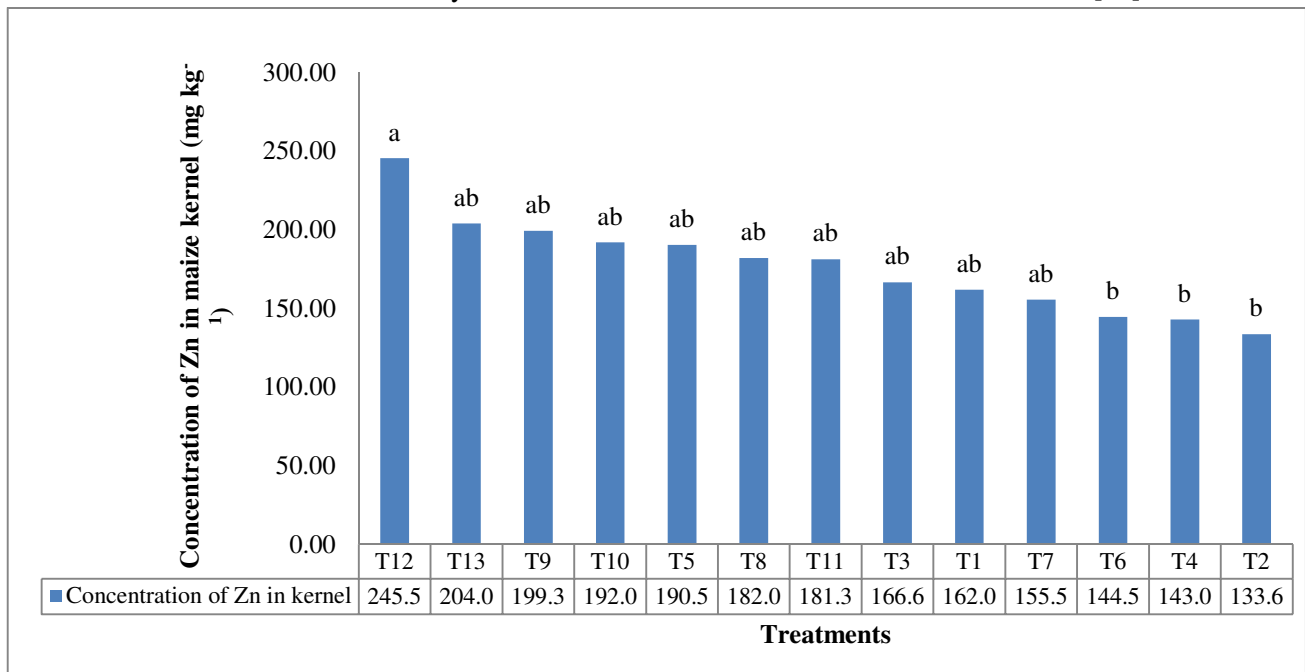


Figure-2: Influence of foliar application of Zn, Fe, and Cu in individual and combined on the concentration of Zn content of maize kernel.

### Iron concentration in maize kernel

Figure (3), show that the concentration of Fe in the maize kernel was significantly influenced by foliar feeding of studied micronutrients in individual and combination at ( $P \leq 0.05$ ). The highest concentration of Fe in maize kernel was ( $767.50 \text{ mg kg}^{-1}$ ) found in treatment (T12) which was significantly higher than all other treatments, while the lowest value ( $386.10 \text{ mg kg}^{-1}$ ) was found in the control treatment (T1). These results are in agreement with the results obtained by Rahman *et al.*[48], who reported that foliar application of micronutrient can greatly enhance plant increase Fe concentration in maize kernel.

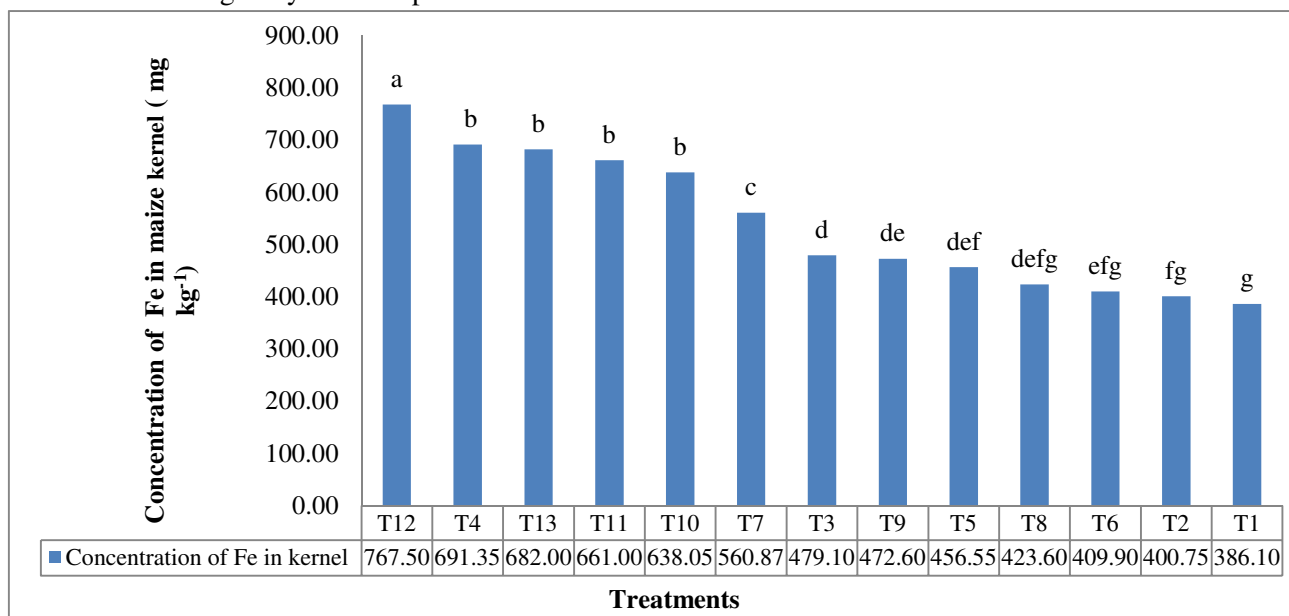


Figure-3: Influence of foliar application of Zn, Fe, and Cu in individual and combined on the concentration of Fe content of maize kernel.

### Copper concentration in maize kernel

Figure (4), show that the concentration of Cu in the maize kernel was significantly influenced by the foliar feeding of studied micronutrients in individual and combination at ( $p \leq 0.05$ ). Depending on the effect of applied foliar levels on concentration Cu in kernel the Cu concentration in the kernel was significantly influenced, the higher mean value was ( $399.33 \text{ mg kg}^{-1}$ ) obtained from treatment (T12), while the lower mean value was ( $390.33 \text{ mg kg}^{-1}$ ) was recorded for treatment (T2). These results are similar to those obtained by Stepien and Wojtkowiak [49].

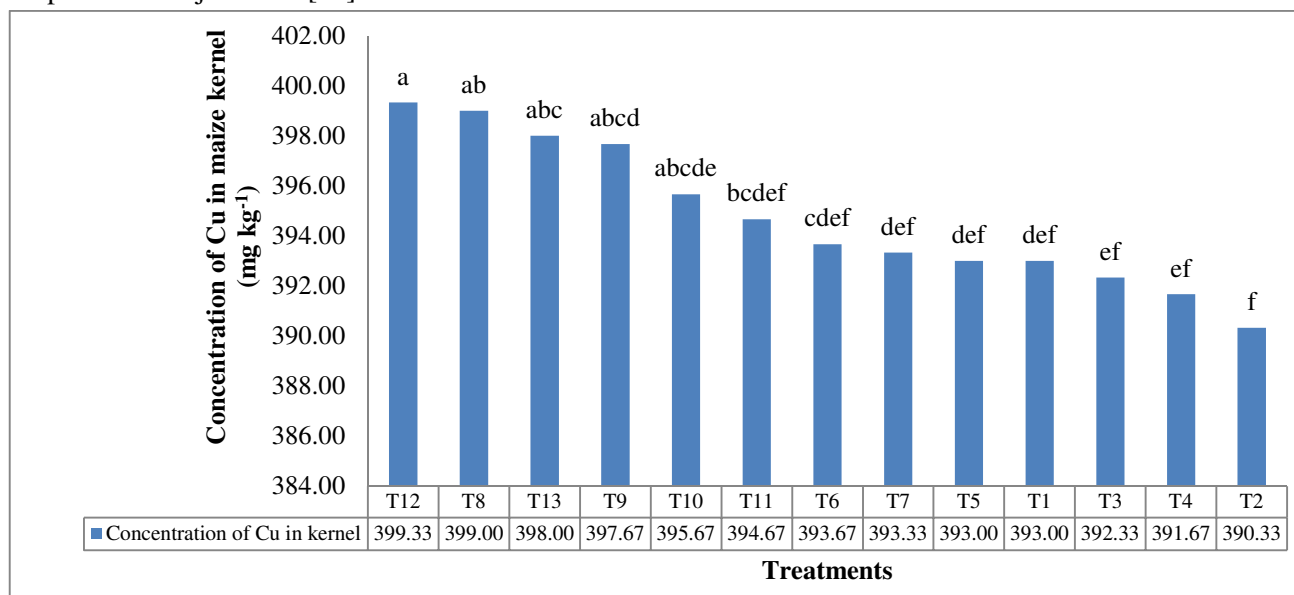


Figure-4: Influence of foliar application of Zn, Fe, and Cu in individual and combined on the concentration of Cu content of maize kernel.

### ***Influence of foliar application of some micronutrients on the uptake of applied micronutrients by the kernel of maize plant:***

Uptake of nutrients by the crop is a function of nutrient content in plant and dry matter production per unit area. The application of fertilizers gradually improved the nutrient uptake by the kernel. The use of micronutrients increased the yield and also nutrient uptake [50].

#### ***Zinc uptake by maize kernel***

The data in Figure (5), confirm that Zn uptake by maize kernel significantly impacted by foliar application of studied micronutrients in individuals and their combinations at ( $P \leq 0.05$ ). Relying on the foliar application of studied micronutrients fertilizer levels in Zn uptake by kernel maize significant differences were found between treatments, the highest mean value was ( $2.95 \text{ kg ha}^{-1}$ ) observed with treatment (T12) which was significantly superior over rest of treatments while the lowest mean value was ( $1.52 \text{ kg ha}^{-1}$ ) found at treatment (T4). Similar results were also reported by Balbaa and Awad[51], who found that the kernel nutrients uptake were affected significantly by the spraying of micronutrients.

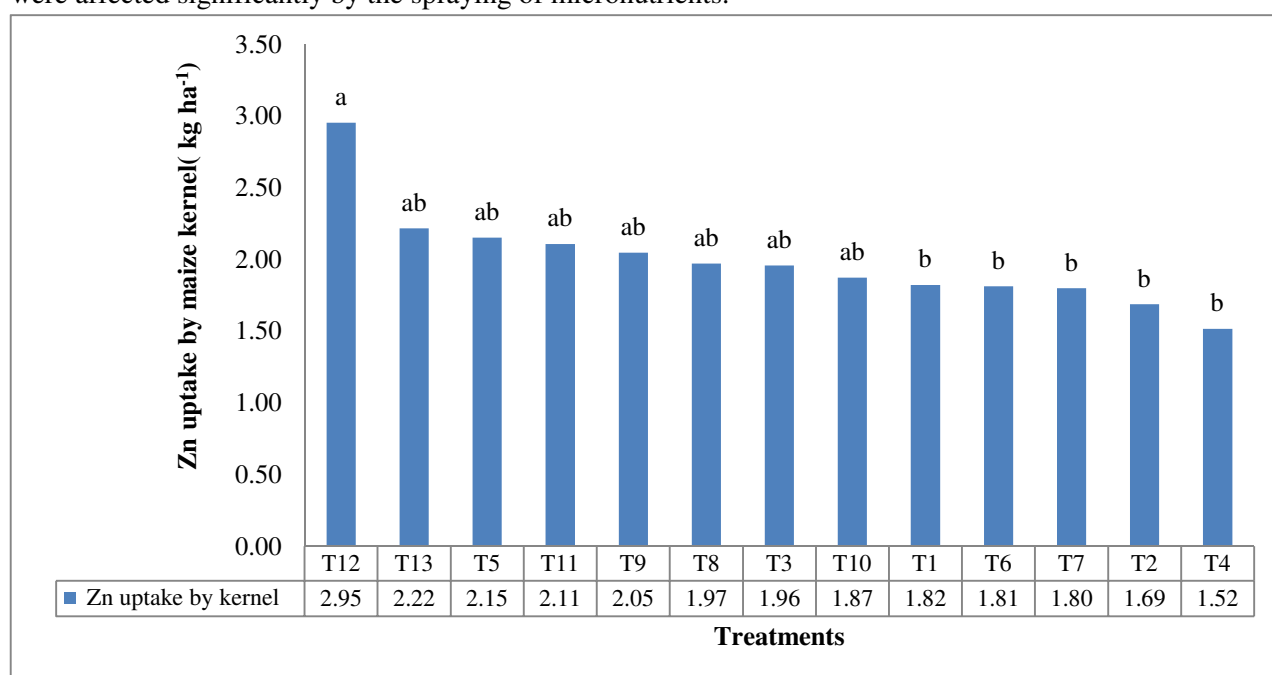


Figure- 5: Influence of foliar application of Zn, Fe, and Cu in individual and combined on Zn uptake by maize kernel.

#### ***Iron uptake by maize kernel***

Figure (6), show that iron uptake by maize kernel was significantly influenced by foliar application of studied micronutrients in individual and combination at ( $p \leq 0.05$ ). Depending on the effects of foliar fertilizer levels in Fe uptake by maize kernel, it was found that significantly influenced, the higher mean value was ( $9.25 \text{ kg ha}^{-1}$ ) obtained at treatment (T12), while the lower mean value was ( $4.44 \text{ kg ha}^{-1}$ ) obtained at control. These results were consistent with the studies of Balbaa and Awad[51].

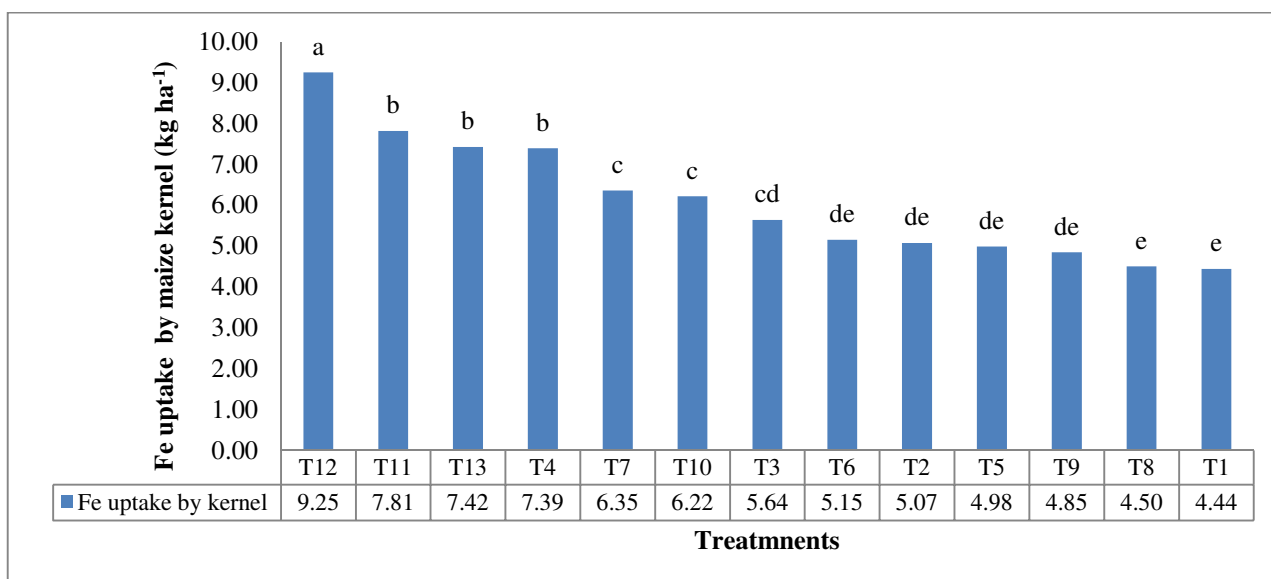


Figure- 6: Influence of foliar application of Zn, Fe, and Cu in individual and combined on Fe uptake by maize kernel.

### Copper uptake by maize kernel

The result in Figure (7) shows that Cu uptake by maize kernel was significantly affected by foliar application of studied micronutrients in individual and combination at ( $P \leq 0.05$ ). The maximum and minimum mean Cu uptake by the kernel was ( $4.94$  and  $3.86 \text{ kg ha}^{-1}$ ), recorded at treatment (T6) and (T10) respectively. These results are in harmony with those obtained by Ramanjineyulu *et al.*[52]. Kumar and Sharma [53] reported that copper uptake is regarded as a process that is regulated metabolically. It is very evident that copper and zinc strongly inhibit the uptake of each other.

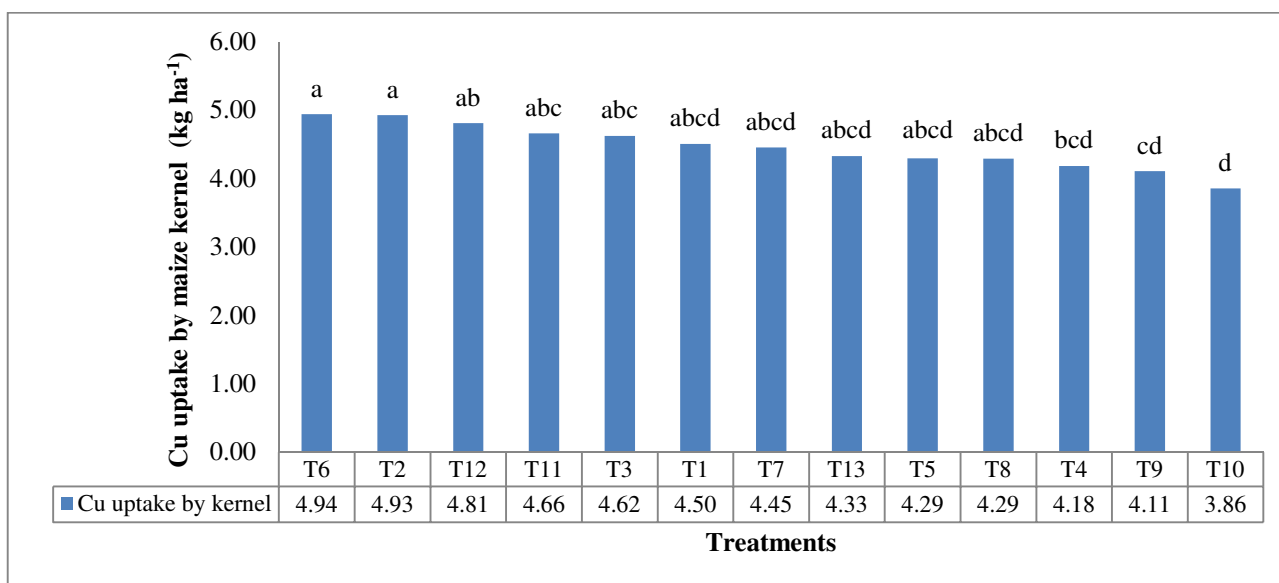


Figure- 7: Influence of foliar application of Zn, Fe, and Cu in individual and combined on Cu uptake by maize kernel.

### Conclusion

Foliar application of micronutrients can improve the nutrient absorption and uptake availability of crops in comparison with soil application and this, in turn, enables greater absorption by maize crops. In general, it can be concluded that the maize kernel yield is considerably improved by the foliar application of micronutrient fertilizers individually and combined. As well as, the improvement of micronutrient uptake by the kernel of the maize plant. The results indicated that the micronutrient mixture was significantly more effective in most cases than single element applications on increasing nutrients uptake.

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