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Effect of some micronutrient application rates on yield and yield components of wheat in calcareous soil of the Iraqi Kurdistan Region

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Abstract

Wheat is the main essential cereal grain crop for food in the world. Management of nutrient is an important factor to increase its productivity. To evaluate the role of micronutrients in improving wheat yield, two field experiments were conducted by application of Zn, Cu, and Fe to the soil in individually and combined forms the source of micronutrients are $ZnSO_4$, $CuSO_4$ and Fe-EDDHA (Ethylenediamine Di-2-Hydroxyphenyl Acetate Ferric) 6% Fe. The number of treatments was thirteen treatments, and the experimental design is Randomized Complete Block Design (RCBD) with three replicates. Results showed that the application of Zn, Cu, and Fe in individually or combined forms were, not affected on the yield and yield components of wheat crop, except for plant height (cm), tillers per plant, 1000-grain weight (g) and harvest index from Bakrajow location While from Kanypanka location plant height (cm) and grain per spike were affected significantly.

Introduction

Wheat (*Triticum aestivum* L) is one of the most important crops among all cereals consumed by the people in a different form for human nutrition in the world and has been cultivated in calcareous soil in the arid and semi-arid region as well as in Kurdistan Region of Iraq. Besides this, it is necessary to livestock and industrial uses also. Micronutrients have prominent effects on dry matter, grain yield and straw yield in wheat[1]. El-Foult, 1983 [2] reported that the availability of micronutrients such as Fe, and Zn is much affected by pH and $CaCO_3$ content and soil texture usually micronutrient-deficiency problems are bound in the calcareous soil of arid and semi-arid regions. Micronutrients play a vital role in development and growth of plants and occupy a major essentiality in increasing crop yields [3]. Deficiency of micronutrients is extensive in most of the Asian countries due to the calcareous nature of the soils, high pH, low organic matter, salt stress, continuous drought, high bicarbonate content in irrigation water, an imbalance in the application of NPK fertilizers [4]. The essentiality of micronutrients not less than macronutrients for plant nutrition because the deficiency of micronutrients causes a considerable reduction in the yield [5]. Plant nutrition in addition to the micronutrients depending on the soil characteristics like the ability of the soil to provide these nutrients to the soil solution [6]. The high-yielding varieties of plants coupled with increasing the consumption of micronutrients from the soil, because the uptake of metal by plants characterized by selectivity, accumulation and the nature of genotypes [7]. Reddy, 2004 [8] reported that Zn, Cu, Fe, and Mn, had an important role in chlorophyll formation, nucleic acid, protein synthesis and played a crucial role in increasing the activities of several enzymes of photosynthesis as well as respiration. Zinc has an important role either as a metal component of enzymes and a functional, structural or regulatory cofactor of a large number of enzymes, membrane integrity, and phytochrome activities [9,10]; Cu is important for physiological redox processes, pollen viability and lignifications [11], and Iron plays a role in biological redox system, enzyme activation and oxygen carrier in nitrogen fixation [12]. Many reports previously have evaluated the response of wheat crop micronutrients (soil or foliar) applications, but little information is available for the combined application of Zinc, Cu and Fe under field conditions, for this reason, the present investigation was conducted in order to evaluate the role of individual and combined between of Zn, Cu, and Fe on yield and yield components of wheat in calcareous soil from Kurdistan Region of Iraq

Material and Methods

A.Experimental Design

The field experiments were conducted at two different locations, the first one at Bakrajo Agricultural Research farm (35^{o} 32^{-} 31.8$^{=}$ N 45^{o} 21^{-} 049$^{=}$ E) and the second one at Kanypanka Agricultural Research farm (35^{o} 22^{-} 25$^{=}$ N 45^{o} 43^{-} 25$^{=}$ E) under rain-fed condition during winter growing season of 2014-2015. The experiments were laid out in a Randomized Complete Block Design (RCBD) with three replications. Three different doses of zinc, copper, and iron have applied in individually and combined in the form of $ZnSO_4$, $CuSO_4$ and Fe-EDDHA (Ethylenediamine Di-2-Hydroxyphenyl Acetate Ferric) 6% Fe. Basel fertilizer dose of NPK was 200-200-150 kg ha^{-1} in the form of Urea, Triple Super Phosphate and Potassium Sulphate respectively were applied to all treatments. .Half dose of nitrogen and a full dose of P_2O_5 and K_2O were applied at the time of sowing while remaining nitrogen was applied after 20 days of germination. Sowing was done by a man driven hand drill with the plant to plant and row to a row distance of 10 and 30cm, respectively. The net plot size was 2 x 3 m^2 the distance between plots was 1 m, and the distance between blocks was 2 m. A recommended seeding rate of 140 kg ha^{-1} of wheat variety *simito* was used. The detail of treatments are given as follow:

T_1= control	T_8= Fe (8 kg ha^{-1})
T_2= Zn (5 kg ha^{-1})	T_9= Fe (12 kg ha^{-1})
T_3= Zn (10 kg ha^{-1})	T_{10}= Fe (16 kg ha^{-1})
T_4= Zn (15 kg ha^{-1})	T_{11}= Zn + Cu + Fe (5 + 6+ 8 kg ha^{-1})
T_5= Cu (6kg ha^{-1})	T_{12}= Zn + Cu + Fe (10 + 8+ 12 kg ha^{-1})
T_6= Cu (8 kg ha^{-1})	T_{13}= Zn + Cu + Fe (15 + 10+ 16 kg ha^{-1})
T7= Cu (10 kg ha^{-1})	

The wheat crop from Bakrajo location was harvested on 6th/June/2015, while at Kanypanka location the harvest was conducted on 7th/ June/2015.

B. Soil Sample Collection and Physicochemical analysis

Soil samples were taken from 0 to 30 cm depths of the soil used in the field experiments; then air dried thoroughly mixed, ground passed through a 2 mm sieves and stored in plastic bottles prior to analysis. Some physical and chemical properties of the soil are given in Table 1. Soil particle size distribution was determined by the pipette method according to Gee and Bauder, 1986 [13]. Electrical conductivity (EC) and pH were measured for the soil saturation extract with EC-meter, model (Herman, Paulsn) and a pH-meter, The model (WTW respectively. Organic matter was determined by dichromate oxidation (Walkley and Black method) as described by Nelson and Sommer, 1986 [14]. The total calcium carbonate equivalent was determined by a rapid titration method as described by Rayment and Higginson, 1992 [15].Cation Exchange Capacity (CEC) was determined by saturation with 1*M* NaOAc at pH 8.2 as described by Suarez, 1996 [16].Soluble HCO_3^- , Cl^- and Ca^{2+} + Mg^{2+} titration methods, Na^+ and K^+ were determined by using (Flame Photometer) as described by Page *et al.*, 1982 [17]. Available P was determined by Olsen *et al.*, 1954 [18] methods. The micronutrients (Zn, Cu, and Fe) were extracted by DTPA according to the procedure of Lindsay and Norvell, 1978 [19], and they are measured by AAS PerkinElmer 800.

Table-1: Some physical and chemical properties of the soil of Bakrajo and Kanypanka used in a field experiment.

Location	*Physical properties of the studied soil Particle Size Distribution (PSD) g kg^{-1}*						
	Sand		*Silt*		*Clay*		*Texture Class*
Bakrajo	*75.40*		*518.40*		*406.20*		*Silty clay*
Kanypanka	*234.00*		*570.00*		*196.00*		*Silty loam*
	Chemical properties of the studied soil						
	pH	EC_e dS m^{-1}	*OM* g kg^{-1}	*CEC* Cmol$_c$ kg^{-1}	*Available P* mg kg^{-1}	*CaCO$_3$ equivalent g kg^{-1}* Total	Active
Bakrajo	*7.80*	*0.38*	*16.06*	*29.76*	*9.61*	*230.00*	*117.00*
Kanypanka	*8.05*	*0.16*	*22.03*	*22.10*	*7.44*	*195.00*	*100.00*
	Soluble ions mmol L^{-1}						
	Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3^-	Cl^-	SO_4^{2-}
Bakrajo	*2.20*	*1.80*	*0.10*	*0.13*	*2.34*	*0.80*	*0.88*
Kanypanka	*1.20*	*1.05*	*0.19*	*0.05*	*3.20*	*0.90*	*0.91*
	Available micronutrients mg kg^{-1}						
	Zn		*Cu*			*Fe*	
Bakrajo	*0.450*		*4.96*			*3.23*	
Kanypanka	*1.563*		*5.07*			*5.15*	

C.Measurement Parameters

The measurement parameters comprise most of the yield components of wheat, such as plant height (cm), number of tiller per plant, number of grain per spike, grain yield (ton ha^{-1}), 1000-grain weight (g), biological yield (ton ha^{-1}), protein content, harvest index% and leaf chlorophyll content.

D.Harvest Index (HI%)

Harvest index (HI)(%) was calculated by using the following formula:

$$Harvest\ index\ (HI)(\%) = \frac{Grain\ Yield}{Biological\ Yield} x100 \qquad (1)$$

E.Grain Protein Content (%)

Grain protein contents were estimated as described by Merrill and Watt, 1973 [20] Protein contents were calculated by multiplying nitrogen by a factor of 5.70.

F.Leaf Chlorophyll Content (LCC) (SPAD Value)

Corresponding reading of chlorophyll content taken with a portable chlorophyll meter was determined. Chlorophyll meter readings were made using Minolta SPAD 502 chlorophyll meter [21]

G. Statistical Analysis

Statistical data analysis like pair-wise comparison (Duncan's multiple range test) was performed by XLSTAT version 7.5 [22]

RESULTS AND DISCUSSION

A. Plant Height (cm)

The data presented in Table 2 and 3 revelated that the application rates of Cu (8 kg ha^{-1}) and Fe (12 kg ha^{-1}) in Bakrajo and Kanypanka location respectively which were superior significantly at (P = 0.05) to all other treatments, while at Kanypanka location there were no significant differences among treatments except (T1, T_{12}, and T_{13}. Maximum plant height (92.47 cm and 96.97 cm) was obtained from T_{11} and T_9 for Bakrajo and Kanypanka location respectively. Minimum plant height (84.60 cm and 89.60 cm) were obtained from T_6 and T_3 for Bakrajo and Kanypanka location respectively. Similar findings were earlier reported by Zain *et al.*, 2015 [23], who found that the application of micronutrients significantly increased the plant height of wheat.

B. Number of Tiller Plant^{-1}

The environment, plant nutrition, and genotype of the plant influence the number of tillers $plant^{-1}$ [23]. The statistical analysis of the data present in Table 2 and 3 show that the application rates of (Zn (10 kg ha^{-1}) + Cu(8 kg ha^{-1}) + Fe(12 kg ha^{-1}) , which was superior significantly to all other treatments at Bakrajo location ,the maximum number of tillers (7.47) were obtained in combination treatment (T_{12}). Whereas, considerable minimum tillers (4.73) were observed in T_1. These results are in agreement with the results of Islam *et al.*1999 [24], who corroborated that zinc application improved productive tillers $plant^{-1}$. While the previous micronutrients had not affected significantly by the number of tillers $plant^{-1}$ from the Kanypanka location the maximum number of tillers, (7.67) were recorded from T_9 whereas the minimum tillers (6.33) obtained from T_1. These results are in a harmonic with the results of Asad and Rafique [1] who found that the application of zinc, copper, iron, manganese, and boron had non-significant at 5% level of significance on the number of tillers m^{-2}.

C. Number of Grain Spike^{-1}

The number of grain per spike which is an important yield component of the wheat plant not affected significantly by the application of micronutrients statistically from the Bakrajo location the maximum number of grains per spike (75.40) were noticed in $T_{8,}$ and the minimum number of grain per spike (62.67) were found from T_4. While at Kanypanka location the highest mean value of a number of grains per spike was (90.27), which was superior significantly to all other treatments. Maximum grains(90.27) were produced by T_9 while T_1 produced a minimum number of grains(70.27). These results in agreement with the finding by Khan *et al.*, 2010 [25]who concluded that the application of micronutrients affects the number of grain per spike of the wheat plant.

D. Grain Yield (ton ha^{-1})

The data relating to grain yield (ton ha^{-1}) are present in Table 2 and 3, revealed that grain yield was not affected significantly ($P<0.05$) by the application of Zn, Cu, and Fe to the soil. Highest grain yield (8.97 and 5.56 ton ha^{-1}) was produced by T_9 and T_{12} from Bakrajo and Kanypanka respectively. While minimum grain yield (6.45 and 4.65) was produced by T_1 and T_2 from Bakrajo and Kanypanka respectively. These results are not matching with finding by Ziaeian and Malakouti, 2001 [26] and Maralian, 2009 [27]. They concluded that the application of micronutrients improved grain yield of the wheat plant.

E. 1000-Grain weight (g)

According to the analysis of variance Table 2 and 3, the mean comparison showed that the applicate rate of (Fe 8kg ha^{-1}) was superior to all other treatments at Bakrajo location but not significantly from the Kanypanka location. Maximum 1000-grain weight (56.67 and 45.00 g) was obtained T_8 and T_7 from Bakrajo and Kanypanka respectively. While the minimum 1000-grain weight(46.67 and 37.33 g) was obtained from T_5 and T_9 of Bakrajo and Kanypanka respectively. Boorboori *et al.*, 2012 [28] reported that the soil application with Fe, Zn, Cu, and Mn effect on 1000 grain weight was significant at the level of 1 %.

Biological Yield (ton ha^{-1})

The result regarding biological yield (ton ha^{-1}) of wheat is shown in Table 2 and 3 which showed that the application of Zn, Cu, and Fe to the soil not affected significantly on biological yield from both locations Bakrajo and Kanypanka. The maximum biological yield (20.32 and 14.58 ton ha^{-1}was produced by T_4 and T_{11} from Bakrajo and Kanypanka respectively. Whereas the minimum biological yield (15.65 and 11.28 ton ha^{-1}) was obtained from T_1 and T_2 for Bakrajo and Kanypanka location respectively. These results not in a harmonic with the finding by Khan *et al.*, 2010 [25] and Webb and Loneragan, 1990 [29].They concluded that the application of micronutrients enhanced the biological yield of the wheat plant.

F. Protein%

The data concerning protein% in grain wheat are shown in Table 2 and 3, and it revealed the soil application of Zn, Cu, and Fe had not a significant ($P<0.05$) effect on protein% content in grain of wheat for both of studied locations Bakrajo and Kanypanka. The maximum protein% (17.20% and 16.83%) were observed in T_8 and T_6 for Bakrajo and Kanypanka respectively. While the minimum protein content (14.90% and 15.33%) was recorded from T_2 and T_{13} for Bakrajo and Kanypanka location respectively. These results are similar to the results finding by Boorboori *et al.*, 2012 [28]. They found that different types of soil fertilizing and solution spraying with Fe, Zn, Mn, and Cu on the level of grain protein did not show any statistically significant effect in barley plant (*Hordeum vulgare* L.).

G. Harvest index%

The statistical analysis of variance in Table 2 and 3 showed that the Zn, Cu, and Fe fertilizers application to the soil affected significantly ($P<0.05$) from Bakrajo location but not affected significantly from Kanypanka location. The maximum harvest index (52.67% and 44.00%) was produced by T_9 and T_{13} from Bakrajo and Kanypanka location respectively. Whereas the minimum harvest index (38.90% and 35.00%) was observed in T_2 and T_{11} from Bakrajo and Kanypanka location respectively. The results of harvest index for Bakrajo location in a harmonic with the results of Zain *et al.,* 2015 [23], who found that harvest index of each treatment due to a foliar spray of micronutrients was noticeably different from other treatments. But the results of harvest index for Kanypanka location in agreement with the finding by Hussain *et al.,* 2005 [30], who found that the application of micronutrients did not affect significantly to harvest index of the wheat crop.

H. Leaf Chlorophyll Content (LCC) (SPAD Value)

The effect of the application of Zn, Cu, and Fe in the leaves of the wheat plant is given in Table 2 and 3. The statistical analysis of variance of the data showed that there were no significant differences between all treatments except (Zn 10kg ha^{-1}) and (Cu 8 kg ha^{-1}) at Bakrajo location.While no significant differences were noticed for all treatments at Kanypanka location. Maximum SPAD value of leaf chlorophyll content (79.90 and 93.53) was recorded from T_3 and T_7 to Bakrajo and Kanypanka location respectively. Whereas the minimum SPAD value of leaf chlorophyll content (60.03 and 69.97 SPAD value) was from T_6 and T_{11} for Bakrajo and Kanypanka location respectively. These results disagree with the finding by Al-Qing *et al.*, 2011 [31]. Who found that the application of Zn and Fe are leading to increasing in the leaf chlorophyll content of the wheat crop.

Table -2: Effect of some micronutrients application to the soil on yield and yield components of wheat at maturity at Bakrajo location.

Treatments	Plant height (cm)	No. of tiller/plant	No. of Grain/ Spike	Grain yield ton ha^{-1}	1000-Grain weight (g)	Biological yield ton ha^{-1}	Protein%	Harvest index%	LCC*(SPAD value)
T_1	89.53^{abcd}	4.73^{d}	64.33^{a}	6.45^{a}	50.67^{ab}	15.65^{a}	15.50^{a}	40.73^{ab}	68.10^{ab}
T_2	87.27^{cde}	5.73^{cd}	73.00^{a}	5.56^{a}	51.33^{ab}	17.65^{a}	14.90^{a}	38.90^{b}	69.83^{ab}
T_3	84.87^{e}	5.87^{cd}	69.00^{a}	8.20^{a}	50.67^{ab}	19.65^{a}	16.40^{a}	42.20^{ab}	79.90^{a}
T_4	91.53^{ab}	6.07^{bc}	62.67^{a}	8.03^{a}	48.00^{b}	20.32^{a}	15.83^{a}	39.43^{b}	66.37^{ab}
T_5	89.13^{abcd}	6.13^{bc}	72.00^{a}	7.70^{a}	46.67^{b}	17.82^{a}	16.57^{a}	42.67^{ab}	74.37^{ab}

T_{6}	84.60^{e}	5.80^{cd}	68.33^{a}	6.98^{a}	53.33^{ab}	16.48^{a}	15.43^{a}	42.07^{ab}	60.03^{b}
T_{7}	89.33^{abcd}	6.47^{abc}	65.87^{a}	8.59^{a}	50.00^{ab}	19.40^{a}	15.43^{a}	44.23^{ab}	74.87^{ab}
T_{8}	86.60^{de}	7.27^{ab}	75.40^{a}	7.23^{a}	56.67^{a}	18.15^{a}	17.20^{a}	39.80^{b}	62.93^{ab}
T_{9}	88.87^{bcd}	6.33^{abc}	64.40^{a}	8.97^{a}	47.33^{b}	17.65^{a}	16.03^{a}	52.67^{a}	74.13^{ab}
T_{10}	89.87^{abcd}	6.60^{abc}	64.33^{a}	7.61^{a}	48.67^{b}	17.82^{a}	16.23^{a}	42.50^{ab}	60.40^{ab}
T_{11}	92.47^{a}	6.93^{abc}	70.00^{a}	7.27^{a}	48.00^{b}	17.82^{a}	16.60^{a}	41.43^{ab}	68.53^{ab}
T_{12}	90.53^{ab}	7.47^{a}	66.80^{a}	8.03^{a}	50.00^{ab}	18.82^{a}	16.60^{a}	42.63^{ab}	67.87^{ab}
T_{13}	89.47^{abcd}	6.20^{bc}	65.67^{a}	7.65^{a}	50.67^{ab}	17.82^{a}	16.07^{a}	43.30^{ab}	65.83^{ab}

Means followed by a similar letter or letters do not differ significantly from each other at 5% level of significance.
*LCC= Leaf Chlorophyll Content (SPAD value)

Table -3: Effect of some micronutrients application to the soil on yield and yield components of wheat at maturity at Kanypanka location.

Treatments	Plant height (cm)	No.of tiller/plant	No. of Grain/ Spike	Grain yield ton ha^{-1}	1000-Grain weight (g)	Biological yield ton ha^{-1}	Protein%	Harvest index%	LCC* (SPAD value)
T_{1}	96.07^{ab}	6.33^{a}	70.27^{i}	5.45^{a}	39.67^{a}	13.35^{a}	16.47^{a}	41.00^{a}	86.83^{a}
T_{2}	89.73^{e}	6.67^{a}	83.73^{bcd}	4.65^{a}	39.33^{a}	11.28^{a}	16.17^{a}	42.00^{a}	76.20^{a}
T_{3}	89.60^{e}	6.67^{a}	81.20^{de}	4.90^{a}	40.00^{a}	11.88^{a}	15.93^{a}	41.00^{a}	85.40^{a}
T_{4}	92.93^{bcde}	6.67^{a}	81.73^{cde}	5.48^{a}	40.67^{a}	13.12^{a}	16.00^{a}	41.00^{a}	74.83^{a}
T_{5}	90.40^{de}	6.67^{a}	84.20^{bc}	4.80^{a}	40.00^{a}	12.72^{a}	15.83^{a}	38.00^{a}	83.80^{a}
T_{6}	92.83^{bcde}	6.33^{a}	79.07^{ef}	5.14^{a}	41.33^{a}	12.35^{a}	16.83^{a}	42.00^{a}	79.50^{a}
T_{7}	92.87^{bcde}	6.33^{a}	85.80^{b}	5.17^{a}	45.00^{a}	14.15^{a}	16.10^{a}	37.00^{a}	93.53^{a}
T_{8}	93.87^{abcd}	6.67^{a}	76.83^{fgh}	4.77^{a}	40.00^{a}	11.82^{a}	16.37^{a}	41.00^{a}	83.93^{a}
T_{9}	96.97^{a}	7.67^{a}	90.27^{a}	5.51^{a}	37.33^{a}	13.98^{a}	16.03^{a}	39.00^{a}	79.33^{a}
T_{10}	90.97^{cde}	6.67^{a}	74.13^{h}	5.17^{a}	40.67^{a}	13.28^{a}	16.07^{a}	40.00^{a}	85.70^{a}
T_{11}	94.40^{abc}	6.67^{a}	76.07^{gh}	4.94^{a}	42.67^{a}	14.58^{a}	15.80^{a}	35.00^{b}	69.97^{a}
T_{12}	91.63^{cde}	6.67^{a}	79.53^{ef}	5.56^{a}	40.00^{a}	13.35^{a}	15.73^{a}	41.00^{a}	82.87^{a}
T_{13}	93.63^{abcd}	6.33^{a}	78.20^{fg}	5.33^{a}	42.67^{a}	12.12^{a}	15.33^{a}	44.00^{a}	75.27^{a}

Means followed by a similar letter or letters do not differ significantly from each other at 5% level of significance.
*LCC= Leaf Chlorophyll Content (SPAD value)

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