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Importance of Micronutrients and its Application Methods for Improving Maize (*Zea mays* L.) Yield Grown in Clayey Soil

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Abstract: Two field experiments were carried out to investigate the effect of adding Zn, Mn and Fe in different methods on maize yield and nutrients concentration. The experimental factors were A: Micronutrients addition. There were 5 treatments 1-Non fertilized. 2- Zn. 3- Mn. 4- Fe. 5- Zn + Mn + Fe. B: Application method. There were 3 methods 1-Foliar spray. 2- Grain soaking. 3- Grain coating. Results revealed that micronutrient fertilization using Zn + Mn + Fe treatment was the most effective treatment in all studied traits. Foliar spraying gave the highest values of ears/plant, grains/ear, 100-grain weight and grain yield in both seasons.

Key words: Micronutrients (Mn, Fe and Zn) % Foliar spray % Grain soaking % Grain coating % Maize

INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop of the world and has economic value in livestock [1]. It is considered as one of the two important cereal crops in Egypt and plays a fundamental role in human and animal feeding [2]. Increasing maize production during the last period became one of the most important goals of the Egyptian government to satisfy human and animal demands. In the last two decades, several investigators in Egypt reported positive response of different field crops to micronutrient fertilization [3-5]. Micronutrients are required in small amounts and they affect directly or indirectly photosynthesis, vital processes in plant such as respiration, protein synthesis, reproduction phase [6]. El-Akabawy *et al.* [2] stated that the beneficial effects of micronutrients application were recorded by many workers on soils of Egypt. Manganese has an essential role in amino acid synthesis by activating a number of enzymes particularly decarboxylases and dehydrogenases of the tricarboxylic acid cycle [6, 7]. Ashoub *et al.* [8] showed that using grain coating of Mn increased plant height, dry weight /plant, green leaves /plant, weight of 100-grain, grain yield, straw yield, Mn uptake and protein content in grains. El-Gizawy [9] found that the highest grain yield was recorded by foliar application or grain soaking with Mn. Iron is a constituent of many enzymes involved in the nutritional metabolism of plant [6, 7]. Zinc plays an important role as a metal component of enzymes (superoxide dismutase, carbonic anhydrase and RNA polymerase) or as a functional, structural, or regulator cofactor of a large number of enzymes [6, 7]. Kanwal *et al.* [10] found that zinc application to soil had a positive significant effect on grain yield. Rego *et al.* [11] reported an increase in grain yield of maize by Zn application.

The aim of this work is to study the effect of micronutrients and its application methods on maize yield, yield components and nutrients concentration.

MATERIALS AND METHODS

Two field experiments were carried out in the Agricultural Research and Experimental Center, Faculty of Agriculture at Moshtohor, Kalubia Governorate, Benha University, Egypt during 2007 and 2008 seasons. The aim of this work is to study influence of some micronutrients and its application methods on maize S.C 10 yield and nutrients uptake. The soil was clay textured with 19 mg/kg organic matter. Physical and chemical properties of the soil were determined according to the standard procedures described by Black [12] (Table 1).

Design of the Experiment: Fifteen treatments were used in the experiment which was the combinations of five micronutrient treatments i.e. Non-fertilized, Zn, Mn, Fe and (Zn + Mn + Fe) as well as three application methods

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Table 1: Characteristics of the experimental soil in study seasons.

Soil properties	1st Season	2nd Season
(0-20)cm		
Physical analysis	25	25.5
Sand, %	19.9	19.3
Silt, %	55.1	55.2
Clay, %	Clayey	Clayey
Texture		
Chemical analysis	19.3	19
Organic matter (g /kg)	8	7.91
pH 1:2 w/w soil water suspension	2.3	2
EC, dS/ m (soil paste extract)	28.9	35.5
$CaCO_3$ (g/ kg)		
Available nutrients (mg /kg)	10.2	10.42
P($NaHCO_3$-extractable)	254	265
K(neutral NH_4-acetate extractable)	16.3	15.03
N (Nitrate-N) KCl-extractable	2	2.33
Zn (DTPA-extractable)	8.52	9.21
Mn (DTPA-extractable)	10	10.07
Fe (DTPA-extractable)		

foliar spray, grain soaking and grain coating. The experimental design was a split plot design with three replications where the micronutrient treatments occupied the main plots and application methods were allocated in the subplots. Plot size was 10.5 m2 (3 x 3.5) having 5 ridges of 3 m in length and 0.7 m in width. Zn, Mn and Fe were in form of EDTA (ethylene diamine tetra acetic acid) commercial fertilizers having Zn, Mn and Fe concentrations of 140 g /kg. The EDTA compounds of the above mentioned elements were used by means of solutions containing 85 mg nutrient/L. Microelements were applied as foliar spray after 40 days from seeding. Spray solution was 950 L/ha Soaking maize grains in the same respective solution of microelements for 12 hrs and then after air-dried for 3 hrs before planting. Grains were firstly damped with a solution of a sticky substance (Triton B) and mixed well with the chelated microelements.

Crop Management Practices: Maize S.C 10 sowing date was on 5th and 7th of June in 2007 and 2008 growing seasons, respectively. Two kernels were hand planted in each hill. Phosphorus fertilizer was applied before seeding at the rate of 357 kg Calcium super phosphate (6.7 % P)/ha. Plots were hand-thinned at the V3-V4 leaf stage (before the 1st irrigation) to one plant per hill. The plots were hand hoed twice for controlling weeds before the first and second irrigations. Nitrogen fertilizer was applied at the rate of 285 kg/ha. Ammonium nitrate (NH_4 NO_3-33.5 N %) was used as the nitrogen source in both seasons, which was applied in two equal doses, at the V3-V4 and at V5-V6 leaf stage (before the 1st and 2nd irrigations). Recommended pest control was applied when necessary.

Measured Parameters: Plant and ear heights were measured after 75 days from seeding (average of 10 plants). At growth stage R1 (silking) Chlorophyll meter readings of the ear leaf were taken using a portable chlorophyll meter (SPAD-502, Minolta, Tokyo, Japan) and was expressed in arbitrary absorbance (or SPAD values) [13]. At silking stage, leaf samples were taken from the second and third leaves from the top of plant for chemical analysis. Plant samples were washed with water then dried at 70°C for 48 h. Total elements were analyzed after digestion of plant samples with mixture of concentrated H_2SO_4 and $HClO_4$ acids. The total micronutrient concentrations: Fe, Mn and Zn were analyzed in plant digests using atomic-absorption spectrophotometry. All micronutrient concentrations were expressed in mg/kg DW. At harvest time the following data were recorded on 10 plants taken at random: number of ears/plant, number of grains/ear, the 100-grain weight, ear weight, grain weight/ear. Grain yield (kg/ha) was determined on whole plot basis adjusted to 15.5 % moisture content.

Statistical Analysis: Data were statistically analyzed according to using the MSTAT-C Statistical Software Package [14]. Where the F-test showed significant differences among means, Duncan's test was performed at the 0.05 level of probability to compared means [15].

RESULTS AND DISCUSSION

Maize Growth, Chlorophyll Units and Micronutrients Concentrations: Micronutrients Fertilization: Data presented in Tables 2 and 3 show that micronutrients fertilization using Zn + Mn +Fe treatment was the most effective treatment of all studied traits of plant height, ear height and chlorophyll units value. Treatments involving application of one of the nutrients singly showed slight and non-significant superiority over than non-fertilized treatment regarding plant height. Concerning ear height in season 2007, Mn as well as Fe showed lower heights than others treatments. As for season 2008, though no significant differences between treatments and the non-fertilized treatment were shown, the highest ear height was in non-fertilized treatment followed by Zn + Mn + Fe, Zn, Mn and Fe in that descending order. This indicated that maize is very sensitive to low Zn supply [16, 17]. Regarding Chlorophyll units value, Zn + Mn + Fe treatment was more effective significantly than other treatments. Concerning Mn, Fe and Zn concentrations in leaves, the Zn + Mn + Fe treatment gave greater Mn concentration as compared with other treatments with

Table 2: Main effects of Zn, Mn and Fe addition and its application methods on plant and ear height and chlorophyll content of maize in 2007 and 2008 seasons.

	Plant height (cm)		Ear height (cm)		Chlorophyll SPAD-units	
Treatments	2007	2008	2007	2008	2007	2008
Micronutrients fertilization [M]						
Non-fertilized treatment	266.1b	271.1ab	130.6a	129.5a	45.4c	43.7d
Zn	271.1b	267.9b	131.1a	128.9a	46.7b	48.8b
Mn	268.3b	266.8b	123.4b	126.6a	45.2c	46.8c
Fe	270.5b	267.8b	120.5b	125.6a	45.4c	47.3bc
Zn+ Mn+ Fe	285.6a	277.7a	131.6a	129.4a	51.0a	51.7a
Application method [A]						
Foliar spray	274.0a	273.0a	130.5a	130.7a	49.7a	51.0a
Soaking	273.7a	266.0a	128.0a	129.0a	45.5b	46.2b
Coating	269.3a	271.7a	123.6b	124.3b	45.0b	45.4b
F test Prob.	P>F					
M	**	**	**	N.S	**	**
A	N.S	N.S	**	*	**	**
M*A	N.S	N.S	N.S	N.S	N.S	N.S
CV, %	3.4	3.0	4.2	3.9	3.8	5.4

Means with different alphabets indicate significant difference between treatments by Duncan's multiple range test at p=0.05.*, ** significantly different at 0.05 and 0.01 probability levels, respectively. N.S: not significant.

Table 3: Main effects of Zn, Mn and Fe addition and its application methods on Mn, Fe and Zn concentrations in maize leaves at silking stage in 2007 and 2008 seasons.

	Micronutrient concentrations mg/ kg DW					
	Mn		Fe		Zn	
Treatments	2007	2008	2007	2008	2007	2008
Micronutrients fertilization [M]						
Non-fertilized treatment	32.7b	31.8b	38.7b	39.9c	20.6c	20.3d
Zn	33.1b	32.3b	40.4ab	40.1c	24.3b	25.2b
Mn	35.8a	33.5b	40.7a	40.2bc	26.5a	22.1cd
Fe	33.1b	32.3b	41.3a	41.9ab	24.4b	22.9c
Zn+ Mn+ Fe	35.2a	35.5a	41.9a	43.3a	28.3a	31.0a
Application method [A]						
Foliar spray	34.6a	33.8a	41.5a	42.2a	26.4a	25.4a
Soaking	33.7a	33.3a	40.0b	40.9b	24.2b	24.3b
Coating	33.6a	32.2a	40.4b	40.2b	23.9b	23.1b
F test Prob.	P>F					
M	**	**	*	*	**	**
A	N.S	N.S	*	*	**	**
M*A	N.S	N.S	N.S	N.S	N.S	N.S
CV, %	4.2	5.7	3.4	3.5	7.5	8.3

Means with different alphabets indicate significant difference between treatments by Duncan's multiple range test at p=0.05.*, ** significantly different at 0.05 and 0.01 probability levels, respectively. N.S: not significant.

Table 4: Main effects of Zn, Mn and Fe addition and its application methods on yield of maize and its components in 2007 and 2008 seasons.

	No. ears/plant		No. grains/ear		100-grain wt. (g)		Ear wt. (g)		Grain wt./ear (g)		Grain yield kg/ha	
Treatments	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Micronutrients fertilization [M]												
Non-fertilized treatment	0.93b	1.08a	590.0a	600.5ab	30.5c	30.5c	259.3b	260.8c	227.0b	227.6b	6941.5c	7004.6d
Zn	1.17a	1.18a	596.4a	611.1a	32.0b	32.0bc	261.1b	263.7b	228.7b	231.6ab	7204.5bc	7230.4bc
Mn	1.18a	1.20a	592.2a	601.1ab	34.1a	32.7ab	259.2b	258.3c	229.4b	229.1b	7404.4ab	7126.7cd
Fe	1.26a	1.17a	591.4a	594.7b	31.8b	33.3b	260.2b	253.3d	228.6b	229.3b	7189.5bc	7348.7b
Zn+ M+ Fe	1.22a	1.20a	601.1a	611.1a	33.5a	33.8a	270.7a	269.5a	236.2a	235.4a	7689.3a	8122.4a
Application methods [A]												
Foliar spray	1.23a	1.24a	600.0a	613.0a	34.6a	34.1a	263.9a	265.0a	231.2a	233.4a	7601.2a	7539.1a
Soaking	1.10b	1.13b	591.3a	600.8b	31.3b	32.2b	261.6a	263.0a	229.6a	231.6a	7154.8b	7397.0ab
Coating	1.13b	1.13b	591.3a	597.3b	31.2b	31.1b	260.8a	259.1b	229.2a	227.5b	7101.4b	7163.8b
F test Prob.	P>F											
M	**	N.S	N.S	**	**	**	*	*	*	*	*	**
A	**	**	N.S	**	**	**	N.S	**	N.S	**	**	**
M*A	N.S	*	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
CV, %	7.56	5.17	2.0	1.7	4.9	4.8	1.6	1.1	2.7	1.8	4.7	4.4

Means with different alphabets indicate significant difference between treatments by Duncan's multiple range test at p#0.05.*, ** significantly different at 0.05 and 0.01 probability levels, respectively. N.S: not significant.

significant differences. There was an exception in 2007season where Mn treatment was as superior as the Zn + Mn + Fe treatment but without significant difference. Zn + Mn + Fe treatment showed significant increases of concentrations of both Fe and Zn over the other treatments.

Application Method: Data presented in Tables 2 and 3 show that regarding plant height, foliar spray gave highest values in both growing seasons comparing with other application methods but with no significant differences among them. Concerning ear height, coating gave lower values than spraying or soaking with significant difference, while no significant difference was found between spraying and soaking. Foliar spray showed significant superiority regarding chlorophyll units value comparing with soaking and coating methods in both growing seasons. Foliar spray was the most efficient method in increasing significantly Fe and Zn concentrations in leaves. Also, it gave higher concentration of Mn but with no significant difference comparing with other application methods. Foliar application with micronutrients could be more effective than soil application because it overcomes deficiency problems in the soil [18]. Soaking, though was slightly superior to coating, such superiority was not statistically significant. There was no significant interaction between fertilization and method of application. This indicates that the pattern of response to fertilization treatment was not affected by the method of application.

Yield and its Components

Micronutrients Fertilization: Data presented in Table 4 revealed that the studied plant traits: number of ears/plant, number of grains/ear, 100-grain weight, weight of ear, weight of grains/ear and grain yield increased by applying Zn, Mn and Fe singly or combined. Such increases were particularly significant by the Zn + Mn + Fe treatment with regard to 100-grain weight, ear weight, weight of grains/ear and grain yield. This shows the synergetic role of micronutrients in improving plant growth and other biochemical and physiological activities [19-23].

Application Method: Regarding number of ears/plant, number of grains/ear and 100-grain weight, in both seasons, spraying gave the highest values with significant difference except in case of number of grains/ear in 2007 season, while no significant difference was found between soaking and coating application methods. These results are in harmony with those which obtained by Modaihsh [18] and Potarzycki and Grzebisz [24]. The effect of all methods of micronutrient application gave no significant difference regarding results of ear weight and grain weight/ear in 2007 season. However,

Table 5: Effect of the interaction between micronutrients and application methods on ears number in 2008 season.

	Application methods [A]			
Treatments	Foliar spray	Soaking	Coating	Means
Micronutrients fertilization [M]				
Non-fertilized treatment	1.13cde	1.03e	1.10de	1.08a
Zn	1.30ab	1.13cde	1.13cde	1.18a
Mn	1.20bcd	1.23bc	1.16cd	1.20a
Fe	1.23bc	1.16cd	1.13cde	1.17a
Zn+ Mn+ Fe	1.36a	1.10de	1.13cde	1.20a
Means	1.24a	1.13b	1.13b	--

Means with different alphabets indicate significant difference between treatments by Duncan's multiple range test at p#0.05

in 2008 season, spray and soaking were equally effective and both were superior to coating regarding ear weight and grain weight/ear. Concerning grain yield, spraying gave the highest yield with significant difference in both seasons; soaking and coating were similar in effect in 2007 season, while in 2008 season soaking was slightly higher than coating without significantly difference compared to spraying and coating.

Interaction: Concerning, the interaction between fertilization and the method of application, the previous patterns of response shown by the main effect, whether the effect of micronutrients fertilization, or that of the methods of application occurred with no interaction between fertilization and the method of application. This means that the pattern of response to fertilization nutrients was not affected by the method and vice versa. Except, number of ears/plant in 2008 season there was significant interaction due to application method (Table 5). The three methods were had similar effect when Mn and Fe were applied singly or when no micronutrients were applied. On the other hand, the methods of application differed significantly when Zn was applied. Foliar spray treatment surpassed soaking or coating when Zn was applied singly or in combination (Zn + Mn + Fe). Application of single or combined Zn also surpassed Mn and Fe only when foliar spray was used. Single Zn soaking or coating was similar to the other elements. Application of Zn + Mn + Fe surpassed single foliar Mn or Fe application. While single Mn application surpassed Zn + Mn + Fe only with soaking method.

CONCLUSION

Based on the results obtained, it might be concluded that foliar application of micronutrients could be useful for improving the nutrient status, physiological performance of maize plants. These results are in harmony to those obtained through foliar application of micronutrients [3-5].

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