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Effect of different chelated zinc sources on the growth and yield of maize (*Zea mays* L.)

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Abstract

A field study was conducted at Agronomic Research Area, University of Agriculture, Faisalabad during spring, 2007 to evaluate the effect of different chelated zinc sources on growth and yield of maize (Zea mays L.). Crop was sown on well prepared soil in 1st week of March, 2007. The experiment was laid out according to randomized complete block design. The treatments comprised of different chelated zinc sources: $ZnSO_4$-DTPA, $ZnSO_4$-Fulvate, $ZnSO_4$-Lignosulphonate, $ZnSO_4$-EDTA and $ZnSO_4$-H_2O along with control (no zinc), repeated three times. Results showed that number of cobs plant^{-1}, grain rows cob^{-1} and oil contents did not differ significantly. However, differences among treatments for plant height at harvest (cm), leaf area plant^{-1} (cm^2), stem diameter (cm), cob length (cm), cob diameter (cm), 100-grains weight (g), number of grains cob^{-1}, grains weight cob^{-1}(g), biological yield (tons ha^{-1}), grain yield (tons ha^{-1}) and protein contents (%) were significantly higher. Moreover, results also revealed that $ZnSO_4$-DPTA was found the most effective Zn chelated source among all the treatments. Rest of the chelating agents were not too impressive as they showed varied response for different variables. The result of this experiment suggest further experimentation to explore behaviour of Zn-DTPA with other macro and micro nutrients and to calculate cost benefit ratio for use of Zn chelated compounds.

Key words: Chelated zinc, fertigation, maize, cereal

Introduction

Maize ranks first worldwide while in Pakistan, it is the third most important cereal grain crop after wheat and rice. It is used as a staple food for humans, feed for livestock and raw material for industry. The crop covered an area of 1026 thousand hectares during 2006-07 with production estimated at 2968 thousand tons (Govt. of Pakistan, 2007).

Zinc is essential for plants, animals and man. Today still its deficiency persists in our soils which creates problem in many physiological processes to function normaly (Pendia, 2000). A critical small concentration of zinc is required to perform several key pathways in plants. These pathways have important roles in growth regulation, photosynthesis and sugar formation, fertility and seed production, and defense against disease. These physiological functions will be impaired and the health and productivity of the plants will be adversely affected due to zinc deficiency. Thus resulting in lower yields (or even crop failure) and frequently in poorer quality crop products (Alloway, 2003).

Zinc deficiency in Pakistani soils was first recognized by Yoshida and Tanaka (1969) and later research established the incidence of widespread Zn deficiency in all rice growing areas (Alam, 2004). Global studies ran by FAO (Sillanpa, 1982) revealed that 50% of soil samples collected from 25 countries were deficient in Zn. Zinc deficiency is the most widespread micronutrient disorder among different crops (Romheld and Marschner, 1991). The deficiency of this micronutrient frequently occurs in maize which is very sensitive to low Zn supply (Loue, 1988; Tariq *et al*., 2002).

On calcareous soils, adsorption and fixation reactions can substantially reduce the efficacy of micronutrients. Therefore, chelating agents, such as Ethylenediaminetetraacetic acid (EDTA) and Diethylenetriamenepentaacetate (DTPA), are commonly used to increase the persistence of Zn and other trace elements in the soil solution. Zinc fertilizers could potentially be improved by using chelates that facilitate metal absorption by plant roots (Marschner, 1995).

True chelates are compounds containing ligands that can combine with a single metal ion (e.g. Zn^{+2}) to form a well defined, relatively stable cyclic structure called a chelation complex. These properties are particularly important and useful in agricultural regions with high pH and/or calcareous soils which routinely test low in plant-available Zn. In the chelated form, metal ions are less likely to react and immobilize by the soil components and are more likely to be delivered to the plant root (Mortvedt *et al*., 1999). The aim of this work was to study if complexes

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of Zn with chelating agents could improve availability of Zn to plant for improving growth and yield of maize on alkaline and calcareous soil".

Materials and methods

The proposed research study was conducted at Agronomic Research Area, University of Agriculture, Faisalabad, during spring 2007. Soil samples were taken before sowing of crop at a depth of 30cm for physico-chemical analysis.

Physicochemical Characteristic	**Value**
Texture	Loamy soil
pH	7.75
EC	2.2 d S m^{-1}
SAR	1.7 (mmol $L^{-1})^{1/2}$
Organic matter	0.58%
Phosphorus	4.05 ppm
Potassium	285 ppm
Test element (Zn) DTPA (0.02 M)	0.2 mg kg^{-1} Soil

The experiment was conducted using randomized complete block design (RCBD) having three replications. The experiment was comprised of following treatments.

Treatment	**Source**	**Dose ($L\ ha^{-1}$)**
Zn_0	Control (No Zn)	0.0
Zn_1	$ZnSO_4$-DTPA (Zn 12%)	7.5
Zn_2	$ZnSO_4$-EDTA (Zn 12%)	7.5
Zn_3	$ZnSO_4$-Lignosulphonate (Zn 12%)	7.5
Zn_4	$ZnSO_4$-Fulvate (Zn 12%)	7.5
Zn_5	$ZnSO_4.\ H_2O$ (Zn 12%)	7.5

Maize Hybrid Monsanto-6525 @ 25kg ha^{-1} was sown in 1^{st} week of March using fertilizer @ 250-125-125 NPK (kg ha^{-1}). Full dose of P, K and half dose of N was applied by broadcast at sowing and half N was broadcasted at knee height of crop for all treatments. Crop was sown on ridges that were 75 cm apart using a dibbler with plant to plant distance of 30 cm, placing two seeds per hill. Thinning was done after ten days of emergence. Zn chelates were applied as fertigation after 20 days of emergence of seedlings using recommended dose at the rate of 7.5 L ha^{-1} (900 g ha^{-1}). For this purpose the measured volume of fertilizer solution was taken in beaker and trickled drop by drop along with irrigation.

All other agronomic practices were kept normal and uniform for all the treatments. Data on following observations were recorded during the course of studies.

- ✓ Plant height at harvest (cm)
- ✓ Leaf area $plant^{-1}$ (cm^2)
- ✓ Stem diameter (cm)
- ✓ Number of cobs $plant^{-1}$
- ✓ Cob length (cm)
- ✓ Cob diameter (cm)
- ✓ 100-grains weight (g)
- ✓ Number of grain rows cob^{-1}
- ✓ Number of grains cob^{-1}
- ✓ Grains weight cob^{-1}(g)
- ✓ Biological yield (t ha^{-1})
- ✓ Grain yield (t ha^{-1})
- ✓ Oil contents (%)
- ✓ Protein contents (%)

Results and discussion

Growth indices of maize hybrids

Application of chelated zinc improved the plant height significantly. Comparative study of mean values (Table 1) for plant height revealed significant results varying from 133 cm to 180 cm. Maximum plant height (180.3 cm) was recorded in $ZnSO_4$-DPTA treated plots followed by $ZnSO_4$-EDTA (162 cm), $ZnSO_4$-Lignosulphonate (155 cm) while least plant height was observed in control (133.3 cm). Similar results are reported by NFDC (1998) that addition of Zn to the soil at the recommended rate of 2.75 kg ha^{-1} substantially increased the growth and grain yield of maize. Bukvic *et al.* (2003) also reported positive effects of phosphorus and zinc fertilization on plant height of maize.

Significant effect of Zn chelates on leaf area was observed by using leaf area meter (Coombs *et al.*, 1985). Comparison of mean values revealed significant differences among the treatment means ranging from minimum 276.1 cm^2 in control to maximum 585.2 cm^2 in $ZnSO_4$-DTPA followed by $ZnSO_4$-Fulvate (418.9 cm^2), $ZnSO_4$-EDTA (408.4 cm^2) which were statistically at par. Bakyt and Sade (2002) reported that flag leaf blade area was increased by Zn application in barley.

Stem diameter was also significantly affected by application of zinc chelated sources ranging from 1.73 cm to 2.97 cm. Maximum stem diameter was reported by $ZnSO_4$-DTPA (2.97 cm) followed by $ZnSO_4$-EDTA (2.33 cm). However, it was minimum in controls. In a similar type of study, Bukvic *et al.* (2003) reported the similar increasing trend in this trait with zinc application.

Number of cobs per plant, cob length and cob diameter

The data presented in Table 2 showed non significant results for number of cobs per plant. These results were similar with the findings of Hariss *et al.* (2007) who reported that cob number and grain yield were the same in the treatments when Zn was applied @2.75 and 5.50 kg ha^{-1}.

Table 1. Effect of zinc salts on growth of maize hybrids

Treatment	**Plant Population ha^{-1}**	**Plant Height (cm)**	**Leaf area (cm^2)**	**Stem diameter (cm)**
Zn_0 = Control	43703.7	133.3e	276.1e	01.73d
Zn_1 = $ZnSO_4$-DTPA	44259.3	180.3a	585.2a	02.97a
Zn_2 = $ZnSO_4$-EDTA	44259.3	162.0b	408.4bc	02.33b
Zn_3 = $ZnSO_4$-Lignosulphonate	43703.7	155.0c	380.7d	02.07c
Zn_4 = $ZnSO_4$-Fulvate	43888.9	142.3d	418.9b	01.83d
Zn_5 = $ZnSO_4$. H_2O.	43868.7	141.0d	394.1cd	02.10c
F-value	0.9492ns	095.4388**	217.94**	46.88**
LSD value		005.54	021.30	00.207

Table 2. Effect of zinc salts on number of cobs, cobs length and cob diameters of maize hybrids

Treatment	**Number of cobs $plant^{-1}$**	**Cob length (cm)**	**Cob diameter (cm)**
Zn_0 = Control	1.00	15.93c	3.70d
Zn_1 = $ZnSO_4$-DTPA	1.66	22.83a	5.00a
Zn_2 = $ZnSO_4$-EDTA	1.33	20.03b	4.40b
Zn_3 = $ZnSO_4$-Lignosulphonate	1.00	19.77b	4.27b
Zn_4 = $ZnSO_4$-Fulvate	1.00	21.13ab	4.00c
Zn_5 = $ZnSO_4$. H_2O.	1.33	21.23ab	4.03c
F-value	1.18ns	17.46**	45.95**
LSD value	ns	01.762	0.207

The significant effect of Zn chelates on the cob length of the maize plant revealed that $ZnSO_4$-DTPA (22.8 cm) gave maximum cob length while $ZnSO_4$. H_2O (21.23 cm), $ZnSO_4$-Fulvate (21.1cm), $ZnSO_4$-EDTA (20.0 cm) and $ZnSO_4$-Lignosulphonate (19.8 cm) were found statistically at par. Least cob length was recorded in control (15.93 cm).

Maximum diameter was recorded in the treatment of $ZnSO_4$-DTPA. It was followed by $ZnSO_4$-EDTA and $ZnSO_4$-Lignosulphonate which were statistically at par. However, the least stem diameter was in control where Zn chelates were not applied.

Yield indices of maize hybrid

The results are quite conclusive in predicting the significant impact of zinc treatments on yield indices of maize hybrids. 100-grains weight (g), number of grains cob^{-1}, grains weight cob^{-1}, biological yield (tons ha^{-1}), grain yield (tons ha^{-1}) were affected significantly.

A study of comparison of mean (Table 3) for 100-grain weight showed significant differences among the treatment ranging from 25.71 g in control to 30.20 g in $ZnSO_4$-DTPA followed by $ZnSO_4$. H_2O (29.39 g) and $ZnSO_4$-EDTA (29.17 g) that were found statistically at par while comparing with other treatments. These results were found similar with the findings of Hariss *et al.* (2007) who reported significant results regarding concerned parameter.

It was observed that there was no effect of Zn chelates on increasing number of grain rows cob^{-1}. It may be concluded that Zn chelates applied were not found to be effective in enhancing the number of grain rows per cob.

On the other hand comparison of mean values for number of grains per cob showed significant differences among the treatment means that varied from 491 to 685. Maximum number of grains per cob were reported in $ZnSO_4$-EDTA (685.3) that was statistically at par with $ZnSO_4$-DTPA (674) and $ZnSO_4$-Lignosulphonate (663.7) followed by $ZnSO_4$-Fulvate (610) and $ZnSO_4$. H_2O (599.7) while the least number of grains per cob were recorded in control (491) where Zn chelates were not applied. These results were found similar with the findings of Hariss *et al.* (2007) who reported that there was significant increase in the grains number per cob with the application of Zn. Bakyt and Sade (2002) also accounted that grain number per spike was increased by application of 18 kg Zn ha^{-1} with an increase of 24% as compared with control for wheat crop.

Grain weight per cob significantly enhanced when $ZnSO_4$-DTPA (203 g) was applied as compared with other treatments. $ZnSO_4$. H_2O (175.7 g) and $ZnSO_4$-EDTA (199.8 g) were recorded statistically at par while least grain weight per cob were reported in control (135.3 g).

Significant increase in biological yield were recorded in $ZnSO_4$-DTPA (19.14 tons ha^{-1}) followed by $ZnSO_4$-

Fulvate (18.02 tons ha^{-1}), $ZnSO_4$-EDTA (17.74 tons ha^{-1}). The least biological yield was found in control (14.25 tons ha^{-1}) where no Zn chelates were applied. These results coincide with the findings of Trehan and Sharma (2000) who assessed that wheat, maize and sunflower showed significant response to Zn in term of increase in their dry matter yields. Safaya and Gupta (1979) reported that deficiency of Zn reduce significantly total plant dry matter production varying from 26.6% to 74%, depending on the cultivar of maize. Ma and Uren (2006) observed that the dry weight of shoots and whole plants (shoots + roots) were increased significantly by the application of Zn.

control ranged from 16% to 29% for maize. Mar *et al.* (1996) reported that two sources of fertilizer employed, Zn-EDTA and Zn-Lignosulphonate, gave rise to a good response by the maize, however, the increments of yield and concentration of Zn in the plant were higher for Zn-EDTA. Ellis *et al.* (1964) described that grain yield of maize was increased from 7500 lbs to 8700 lbs per acre by an application of 4 lbs of zinc per acre. Fecenko and Lozek (1998) studied the effect of 1.5, 3 and 6 kg Zn ha^{-1} on maize. They found the highest maize yield (10.90%) with application of 1.5 kg Zn ha^{-1}.

Table 3. Effect of zinc salts on yield indices of maize hybrids

Treatment	100 - Grain weight (g)	Grain rows cob^{-1} (No.)	Number of grains cob^{-1}	Grain weight cob^{-1} (g)	Biological yield (tons ha^{-1})	Grain yield (tons ha^{-1})
Zn_0 = Control	25.71b	14.66	490.7c	135.3c	14.25d	007.16 d
Zn_1 = $ZnSO_4$-DTPA	30.20a	16.00	674.0a	203.0a	19.14a	009.14 a
Zn_2 = $ZnSO_4$-EDTA	29.17a	15.33	685.3a	199.8a	17.74b	008.41 b
Zn_3 = $ZnSO_4$-Lignosulphonate	26.71b	14.00	663.7a	177.3b	16.56c	008.12 bc
Zn_4 = $ZnSO_4$-Fulvate	25.91b	15.33	610.0b	145.3c	18.02b	008.36 b
Zn_5 = $ZnSO_4$. H_2O.	29.39a	15.33	599.7b	175.7b	16.14c	007.80 c
F-value	12.49**	00.60ns	030.99**	036.03**	55.93**	151.71**
LSD value	01.751		041.07	013.02	00.72	000.33

Table 4: Effect of zinc salts on protein and oil contents of maize hybrids

Treatment	Protein content (%)	Oil content (%)
Zn_0 = Control	9.80d	4.29
Zn_1 = $ZnSO_4$-DTPA	11.41a	4.31
Zn_2 = $ZnSO_4$-EDTA	10.33c	4.28
Zn_3 = $ZnSO_4$-Lignosulphonate	10.56b	4.30
Zn_4 = $ZnSO_4$-Fulvate	10.00d	4.29
Zn_5 = $ZnSO_4$. H_2O.	10.44bc	4.30
F-value	**70.60****	**1.33ns**
LSD value	**0.21**	

Study on mean values for grain yield was reported to have significant differences among the treatment means that varied from 7.16 to 9.14 tons ha^{-1}.

Regarding grain yield (tons ha^{-1}) a maximum value was reported in $ZnSO_4$-DTPA (9.14 tons ha^{-1}) followed by $ZnSO_4$-EDTA (8.41 tons ha^{-1}), $ZnSO_4.H_2O$ (7.80 tons ha^{-1}), $ZnSO_4$-Lignosulphonate (8.12 tons ha^{-1}) while the least grain yield were recorded in control (7.16 tons ha^{-1}). These results were found similar with the findings of Bakyt and Sade (2002), who revealed that there were relative increases in grain yield as a result of Zn applications over

Quality parameters for maize

In this section, protein and oil contents were determined and it was obvious from the results that treatments altered protein contents significantly, while oil contents (%) remained non significant.

Mean values (Table 4) for protein were reported to have significant differences among the treatments that varied from 9.80 to 11.41 (%). Maximum protein content was reported in $ZnSO_4$-DTPA (11.41 %) followed by $ZnSO_4$-Lignosulphonate (10.56%), $ZnSO_4.H_2O$ (10.44%),

$ZnSO_4$-EDTA (10.33%), $ZnSO_4$-Fulvate (10.00%) while the least protein contents were recorded in control (9.80%). Data pertaining to oil contents showed non significant variations. It means Zn chelates were not effective to increase the oil contents as compared to the control where Zn chelates were not applied.

Amer *et al.* (1980) reported that maize cultivar Opaque 2 yielded the highest percentage of protein, lysine, potassium and calcium in responses of Zn application. Fecenko and Lozek (1998) reported that crude protein contents in maize grain was increased by 0.91 % by the application of 1.5-3 kg Zn ha^{-1}.

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