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Influence of Zinc Chelates on Yield and Zn Uptake by Maize

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ABSTRACT

New chelated Zn formulations TNAU Zn EDTA (9.7 % Zn) and TNAU Zn citrate (9.0 % Zn) were developed and tested in comparison with $ZnSO_4$ and commercial Zn EDTA in a field experiment with maize crop conducted during 2018-19 at Tamil Nadu Agricultural University, Coimbatore. The experiment was laid out in Randomized Block Design with treatments control (NPK alone), soil application of 7.5 kg Zn ha^{-1} as $ZnSO_4$, 0.75 and 1.5 kg Zn ha^{-1} as TNAU Zn EDTA, TNAU Zn citrate and commercial Zn EDTA, foliar spray of 0.5 % $ZnSO_4$, TNAU Zn EDTA, TNAU Zn citrate and commercial Zn EDTA thrice on 30, 40 and 50 days after sowing (DAS). Significantly highest grain yield (7158 kg ha^{-1}) and stover yield (12741 kg ha^{-1}) were recorded in the treatment foliar spray of 0.5 % TNAU Zn EDTA which remained on par with the application of 1.5 kg Zn ha^{-1} as TNAU Zn EDTA, foliar spray of 0.5 % TNAU Zn citrate and foliar spray of 0.5 % commercial Zn EDTA. Foliar spray of 0.5 % TNAU Zn citrate registered grain yield of 6962 kg ha^{-1} and stover yield of 12115 kg ha^{-1}. Significantly highest grain Zn content and uptake of 32.4 mg kg^{-1} and207 g ha^{-1} respectively were observed in the treatment foliar spray of 0.5% TNAU Zn citrate. Stover Zn content (36.5 mg kg^{-1}) and uptake (436 g ha^{-1}) were significantly highest with foliar spray of 0.5% TNAU Zn EDTA. Percentage yield increase due to foliar spray of 0.5 % TNAU Zn EDTA and 0.5 % TNAU Zn citrate formulations were 12.3 and 9.17 % respectively over $ZnSO_4$ foliar spray. The treatments foliar spray of 0.5 % TNAU Zn EDTA and 0.5 % TNAU Zn citrate thrice on 30, 40 and 50 DAS recorded higher grain and stover yield as well as Zn content and Zn uptake over all other treatments.

Introduction

Zinc deficiency in soil is increasing at an alarming rate due to intensive cropping and reduced use of organic manures. Coarse textured, calcareous, alkaline or sodic soils having sandy texture, high pH and low organic matter are generally deficient in available Zn. Zn was one of the first micronutrients known to be essential for plants, animals and humans (Kabata- Pendias, 2000). Zinc plays a key role in various plant metabolic processes such as development of cell walls, respiration, carbohydrate metabolism and gene expression and regulation (Klug and Rhodes, 1987). Zn is a component of various enzymes involved in metabolic activities in plants. Plants grown on

Zn deficient soils have reduced productivity and contain very low concentrations of Zn in the edible parts. Zn deficiency is a serious nutritional and health problem in human beings, especially in the developing countries where cereal-based foods are dominating the diet. Challenge for agricultural scientists is to feed the ever growing world population with nourishing food.

Zinc sulphate, the major source of zinc has the disadvantage of rapid convertibility. It is reported that chelated zinc shows higher use efficiency than zinc sulphate fertilizer and hence can be applied at 8 to 10 times less dose than their corresponding salts. A chelate is a kind of organic chemical complex in which the metal is held so tightly that it cannot be stolen by the other substances, which could convert it to an insoluble form. Chelates are considered the most effective fertilizers, compared to the inorganic forms, such as sulfates, which can react with CaCO3 forming low-solubility compounds (Loeppert, 1986; Vempati and Loeppert, 1988). Besides, the chelating agents increase the absorption of ions as the roots have more affinity for the chelated micronutrients. Chelated forms of Zn are more commonly used for foliar applications and have the advantage of being compatible with many herbicide and fungicide formulations in spray tank mixes, but they are more expensive than inorganic compounds (Alloway, 2008). An attempt was made to develop new chelated Zn formulations using EDTA and citric acid as chelating agents. The newly developed chelated Zn formulations were evaluated in a field experiment with maize crop.

Materials and Methods

The field experiment was conducted in Zn deficient soil at Eastern Block farm of Tamil Nadu Agricultural University, Coimbatore to evaluate newly developed chelated Zn formulations with maize (TNAU Maize hybrid CO6) as test crop. Newly developed TNAU Zn EDTA (9.7 % Zn) and TNAU Zn citrate (9.0 % Zn) formulations were tested in comparison with $ZnSO_4$ and commercial Zn EDTA. Treatments comprised of control (NPK alone), soil application of 7.5 kg Zn ha^{-1} as $ZnSO_4$, 0.75 and 1.5 kg Zn ha^{-1} as TNAU Zn EDTA,TNAU Zn citrate and commercial Zn EDTA, foliar spray of 0.5 % $ZnSO_4$, TNAU Zn EDTA,TNAU Zn citrate and commercial Zn EDTA thrice on 30, 40 and 50 days after sowing (DAS).

The field experiment was conducted in Randomized Block Design (RBD) with three replications. Soil Test Crop Response (STCR) based NPK fertilizer dose for Maize hybrid was worked out for a yield target of 9 t ha^{-1} andfertilizer N, P_2O_5 and K_2O applied were 259, 96 and 38 kg ha^{-1} respectively. STCR based NPK was applied to all treatments.

Since the experimental soil was deficient in available Fe, recommended dose of $FeSO_4$, (50 kg ha^{-1}) was applied. Crop protection measures were taken up as and when needed. Plant samples were collected at late vegetative stage and harvest stage for assessing the Zn content and uptake. Zn content in plant samples was estimated using Atomic Absorption Spectrophotometer (Jackson, 1973). Grain and Stover yield were recorded. The data obtained were subjected to statistical analysis as suggested by Panse and Sukhatme (1978).

Results and Discussion

The physico chemical characteristics of experimental soil were analyzed and the results are presented in Table 1. The experimental soil belongs to Periyanaickenpalayam series and comes under the taxonomic classification fine, montmorillonitic, isohyperthermic, calcareous

TypicHaplustert. The soil texture was clay loam. The soil was alkaline in reaction (8.07) with permissible amount of soluble salts (0.24 dS m^{-1}).

The experimental soil was calcareous. The organic carbon content of the soil was low (4.79 g kg^{-1}). The soil was low in available N (134 kg ha^{-1}), medium in available P (16.7 kg ha^{-1}) and high in available K (657 kg ha^{-1}). The soil was deficient in DTPA-Zn (0.60 mg kg^{-1}), DTPA-Fe (2.27 mg kg^{-1}), DTPA-Cu (0.89 mg kg^{-1}) and sufficient in DTPA-Mn (5.08 mg kg^{-1}).

Grain and Stover Yield

Regarding grain yield, significantly highest grain yield of 7158 kg ha^{-1} was observed with foliar spray of 0.5 % TNAU Zn EDTA (T_{10}) which was statistically on par with the soil application of 1.5 kg Zn ha^{-1} as TNAU Zn EDTA (T_4), foliar spray of 0.5 % TNAU Zn citrate (T_{11}) and foliar spray of 0.5 % commercial Zn EDTA (T_{12}) (Table 2). MacNacidhe and Fleming (1988) observed significant increase in grain yield due to foliar application of zinc in spring cereals and higher grain yield due to Zn EDTA than Zn sulphate. Similar to this result, Khalid *et al.*, (2013) reported higher grain yield by the foliar application of Zn Ch: EDTA at 180 g Zn ha^{-1} when compared to $ZnSO_4$ and Zn Ch: HEDTA. Similar results were also reported by Syed *et al.*, (2016) and Kulhare *et al.*, (2017). Better performance of Zn EDTA as compared to $ZnSO_4.7H_2O$in bajra was reported by Panda and Doddamani (2018).

Foliar spray of 0.5% TNAU chelated Zn formulations and soil application of 1.5 kg Zn ha^{-1} as TNAU Zn EDTA recorded significantly higher and comparable yield among themselves. The results revealed that foliar spray of Zn chelates performed better when compared to soil application of the same.

The grain yields registered in the treatments soil application of 0.75 kg Zn ha^{-1} as TNAU Zn EDTA (T_3), 1.5 kg Zn ha^{-1} as TNAU Zn citrate (T_6), 1.5 kg Zn ha^{-1} as commercial Zn EDTA (T_8), 7.5 kg Zn ha^{-1} as $ZnSO_4$ (T_2) and foliar spray of 0.5 % $ZnSO_4$ (T_9)were statistically comparable. Significantly lowest value (5867 kg ha^{-1}) was registered in control (NPK alone - T_1) and it remained on par with 0.75 kg Zn ha^{-1} as TNAU Zn citrate (T_5) and 0.75 kg Zn ha^{-1} as commercial Zn EDTA (T_7).

Table.1 Initial soil sample characteristics

pH		8.07
EC	dSm^{-1}	0.24
Organic Carbon	g kg^{-1}	4.79
Available N	kg ha^{-1}	134
Available P		16.7
Available K		657
DTPA-Fe	mg kg^{-1}	2.27
DTPA-Zn		0.60
DTPA-Mn		5.08
DTPA-Cu		0.89

Table.2 Effect of Zn formulations on yield, Zn content and uptake at late vegetative stage of maize

Treatments	Late vegetative stage		Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
	Zn content (mg kg^{-1})	Zn uptake (g ha^{-1})		
T_1-Control (NPK alone)	39.3	260	5867	10088
T_2-7.5 kg Zn ha^{-1} as $ZnSO_4$	41.1	297	6423	11198
T_3-0.75 kg Zn ha^{-1} as TNAU Zn EDTA	42.2	314	6547	11483
T_4-1.5 kg Zn ha^{-1} as TNAU Zn EDTA	43.0	347	6985	12352
T_5-0.75 kg Zn ha^{-1} as TNAU Zn citrate	40.1	273	5937	10415
T_6-1.5 kg Zn ha^{-1} as TNAU Zn citrate	41.6	303	6452	11408
T_7-0.75 kg Zn ha^{-1} as commercial Zn EDTA	39.6	265	5910	10355
T_8-1.5 kg Zn ha^{-1} as commercial Zn EDTA	41.5	287	6182	10662
T_9-Foliar spray of 0.5 % $ZnSO_4$*	42.6	295	6377	11067
T_{10}-Foliar spray of 0.5 % TNAU Zn EDTA *	44.8	365	7158	12741
T_{11}-Foliar spray of 0.5 % TNAU Zn citrate*	44.1	346	6962	12115
T_{12}-Foliar spray of 0.5 % commercial Zn EDTA*	43.2	336	6777	12052
SEd	1.2	15	287	504
CD (P=0.05)	2.5	31	595	1044

*thrice on 30, 40 and 50 DAS

Table.3 Effect of Zn formulations on Zn content and uptake at harvest stage of maize

Treatments	Grain		Stover	
	Content (mg kg^{-1})	Uptake (g ha^{-1})	Content (mg kg^{-1})	Uptake (g ha^{-1})
T_1-Control (NPK alone)	26.5	143	30.8	287
T_2-7.5 kg Zn ha^{-1} as $ZnSO_4$	28.4	166	33.8	354
T_3-0.75 kg Zn ha^{-1} as TNAU Zn EDTA	28.5	172	34.4	365
T_4-1.5 kg Zn ha^{-1} as TNAU Zn EDTA	29.5	192	35.8	416
T_5-0.75 kg Zn ha^{-1} as TNAU Zn citrate	26.8	146	31.8	302
T_6-1.5 kg Zn ha^{-1} as TNAU Zn citrate	29.1	173	34.2	361
T_7-0.75 kg Zn ha^{-1} as commercial Zn EDTA	26.6	145	31.1	298
T_8-1.5 kg Zn ha^{-1} as commercial Zn EDTA	28.6	161	33.2	327
T_9-Foliar spray of 0.5 % $ZnSO_4$*	30.1	172	33.4	341
T_{10}-Foliar spray of 0.5 % TNAU Zn EDTA *	31.1	205	36.5	436
T_{11}-Foliar spray of 0.5 % TNAU Zn citrate*	32.4	207	35.1	396
T_{12}-Foliar spray of 0.5 % commercial Zn EDTA*	30.5	190	34.7	388
SEd	0.8	13	1.0	26
CD (P=0.05)	1.7	26	2.0	54

*thrice on 30, 40 and 50 DAS

With respect to stover yield, the treatment foliar spray of 0.5 % TNAU Zn EDTA (T_{10}) recorded significantly higher stover yield of 12741 kg ha^{-1} (Table 2). Foliar spray of 0.5% chelated Zn formulations and soil application of 1.5 kg Zn ha^{-1} as TNAU Zn EDTA registered comparable stover yields. Stover yields observed with soil application of 0.75 kg Zn ha^{-1} as TNAU Zn EDTA (T_3) was statistically on par with soil application of 1.5 kg Zn ha^{-1} as TNAU Zn citrate(T_6) and commercial Zn EDTA(T_8), soil (7.5 kg Zn ha^{-1}) and foliar application (0.5%) of recommended quantity of $ZnSO_4$. Lowest stover yield of 10088 kg ha^{-1} was noticed in control (NPK alone -T_1).The results are in line with the findings of Ortega-Blu and Molina-Roco (2007) who reported higher corn dry matter with Zn EDTA as compared to $ZnSO_4$.

Zn content and uptake at late vegetative stage

Zn content in maize plant at late vegetative stage varied from 39.3 to 44.8 mg kg^{-1}(Table 2). The treatment foliar spray of 0.5 % TNAU Zn EDTA (T_{10}) recorded significantly higher Zn content and control (NPK alone -T_1) recorded lowest Zn content. This is in agreement with the findings of Teixeira *et al.*, (2019) who reported that Zn content and Zn uptake in the Mombasa grass was directly proportional to the rate of foliar applied chelated Zn, contributing to the yield of better quality forage. The improvement in the Zn concentration and uptake observed in this experiment comparing ZnSO4 and Zn-EDTA, is similar to that reported by Gangloff *et al.*, (2002). Foliar spray of 0.5% Zn formulations and soil application of 1.5 kg Zn ha^{-1} as TNAU Zn EDTA recorded significantly higher and comparable Zn content. With respect to Zn uptake at late vegetative stage, the treatment foliar spray of 0.5 % TNAU Zn EDTA (T_{10}) registered significantly higher Zn uptake of 365 g ha^{-1} (Table 2). Zn uptake in the treatments, foliar spray of 0.5% chelated Zn formulations and soil application of 1.5 kg Zn ha^{-1} as TNAU Zn EDTA were comparable. Lowest Zn uptake of 260 g ha^{-1} was observed in control (NPK alone -T_1).

Zn content and uptake at harvest stage

Grain Zn content ranged from 26.5 to 32.4 mg kg^{-1}(Table 3). Marked variation in grain Zn content was observed among the treatments. Significantly highest grain Zn content was observed in the treatment foliar spray of 0.5% TNAU Zn citrate (T_{11}) which was on par with the treatment foliar spray of 0.5% TNAU Zn EDTA (T_{10}). Both Zn concentration and Zn content in plant shoots were higher in the presence of citrate than in the absence (Chairidchai and Ritchie, 1993). The treatments foliar spray of 0.5% commercial Zn EDTA and $ZnSO_4$, soil application of 1.5 kg Zn ha^{-1} as Zn EDTA and TNAU Zn citrates recorded comparable grain Zn content. Grain Zn content was lowest in control (NPK alone -T_1) which was on par with 0.75 kg Zn ha^{-1} as TNAU Zn citrate (T_5) and commercial Zn EDTA (T_7). Grain Zn uptake varied from 143 to 207 g ha^{-1}. The highest value was recorded in the treatment foliar spray of 0.5% TNAU Zn citrate (T_{11}). Grain Zn uptake in the treatments foliar spray of 0.5% chelated Zn formulations and soil application of 1.5 kg Zn ha^{-1} as TNAU Zn EDTA were comparable. These results are in agreement with the findings of Verma *et al.*, (2015), Islam *et al.*, (2016) and Kulhare *et al.*, (2017). Zn uptake in the treatments, soil application of 1.5 kg Zn ha^{-1} as Zn citrate (T_6) and commercial Zn EDTA (T_8), soil application of 0.75 kg Zn ha^{-1} as TNAU Zn EDTA (T_3), 7.5 kg Zn ha^{-1} as $ZnSO_4$ (T_2) and foliar spray of 0.5 % $ZnSO_4$ (T_9) were statistically on par. Lowest grain Zn uptake of 143 g ha^{-1} was noticed in control (NPK alone -T_1).

Stover Zn content was in the range of 30.8 to 36.5 mg kg^{-1} (Table 3). Stover Zn content was significantly highest with foliar spray of 0.5% TNAU Zn EDTA (T_{10}) and this remained comparable with foliar spray of 0.5% TNAU Zn citrate (T_{11}) and 0.5% commercial Zn EDTA (T_{12}), soil application of 1.5 kg Zn ha^{-1} as TNAU Zn EDTA (T_4). Stover Zn content was lowest (30.8 mg kg^{-1}) in the treatment control (NPK alone -T_1). Stover Zn uptake was significantly highest (436 g ha^{-1}) in the treatment foliar spray of 0.5% TNAU Zn EDTA (T_{10}). Foliar spray of 0.5% chelated Zn formulations and soil application of 1.5 kg Zn ha^{-1} as TNAU Zn EDTA recorded comparable stover Zn uptake values. Lima *et al.,* (2014) observed that Zn fertilization via soil as well as foliar can be adequate strategies to supply of Zn to maize plants. Control (NPK alone -T_1) registered the lowest stover Zn uptake of 287 g ha^{-1}. The increase in both grain and straw yield with application of Zn-EDTA might be due to the relatively greater amount of Zn uptake compared with $ZnSO_4$ application. These results are in agreement with the findings of Karak *et al.*, (2005) who reported that chelated Zn was the most efficient source of Zn for lowland rice production in calcareous soil. Also, Zn mobilisation efficiency was higher with Zn-EDTA than with $ZnSO_4$ for Zn uptake by grain and straw (Naik and Das, 2008). The results are in agreement with Takkar and Singh (1989).

Percentage yield increase due to foliar spray of 0.5 % TNAU Zn EDTA and 0.5 % TNAU Zn citrate formulations respectively were 22.0 and 18.7 % over control, 11.4 and 8.38 % over $ZnSO_4$ soil application and 12.3 and 9.17 % over $ZnSO_4$ foliar spray. The treatments foliar spray of 0.5 % TNAUZn EDTAand0.5 % TNAUZn citrate thrice on 30, 40 and 50 DAS recorded higher grain and stover yield as well as Zn content and Zn uptake over all other treatments.

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