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Influence of Zinc Formulations on Yield, Economics of Maize Crop and Soil Zn Status

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ABSTRACT: To overcome the problem of low use efficiency of inorganic Zn fertilizers, new chelated Zn formulations were developed. Newly developed chelated Zn formulations TNAU Zn EDTA and TNAU Zn citrate were tested in comparison with $ZnSO_4$ and commercial Zn EDTA for soil and foliar application in a field experiment with maize crop conducted during 2019 at Tamil Nadu Agricultural University, Coimbatore. Yield attributes, grain and stover yield were recorded. Economics of treatments was worked out. Significantly highest cob length (21.2 cm), number of grains per cob (269), 100 grain weight (41.2g), 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 (T_{10}) which remained on par with the 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}). Soil application of 7.5 kg Zn ha^{-1} as $ZnSO_4$ (T_2) recorded significantly highest post harvest soil Zn of 0.99 mg kg^{-1}. The highest B:C ratio (2.55) and net income (Rs. 76,375/-) were noticed with foliar spray of 0.5% TNAU Zn EDTA (T_{10}) which was followed by foliar spray of 0.5% TNAU Zn citrate (T_{11}).

Keywords: Maize, Zinc chelates, Yield, Economics, Soil zinc

INTRODUCTION

After green revolution, due to intensive cropping and reduced use of organic manures zinc deficiency in soil is increasing. Generally, Zn deficiency was observed in coarse textured, calcareous, alkaline or sodic soils having sandy texture, high pH and low organic matter. Zn was known to be essential for plants, animals and humans (Kabata-Pendias, 2000). It plays an important role in various plant metabolic processes such as development of cell walls, respiration, carbohydrate metabolism, 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.

Zinc sulphate, the major source of zinc has the problem of rapid convertibility. Chelated zinc fertilizers showed higher use efficiency than zinc sulphate and hence can be applied at 8 to 10 times lesser dose than their corresponding salts. In chelates, the metal is held so tightly that it cannot react with other substances and converted in to insoluble forms. Chelates are considered the most effective, compared to the inorganic forms, such as sulfates (Vempati and Loeppert, 1988). Plant roots have more affinity for chelated micronutrients as the chelating agents enhance the absorption of ions. Chelated forms of Zn are compatible with many pesticide and fungicide formulations in spray tank mixes and are more commonly used for foliar applications, but they are more expensive than inorganic compounds (Alloway, 2008). The most effective sources of zinc fertilizer need to be studied (Palai *et al*., 2020). New chelated Zn formulations using EDTA and citric acid as chelating agents were developed and tested with maize crop.

MATERIALS AND METHODS

A field experiment was conducted during 2019 at Eastern Block farm of Tamil Nadu Agricultural University, Coimbatore to study the influence of newly developed chelated Zn formulations on the performance of maize (TNAU Maize hybrid CO6) crop. Newly developed TNAU Zn EDTA (9.7 % Zn) and TNAU Zn citrate (9.0 % Zn) formulations were compared with $ZnSO_4$ and commercially available Zn EDTA. Treatments included control (NPK alone), soil application (basal) of $ZnSO_4$@ 7.5 kg Zn ha^{-1}. TNAU Zn EDTA,TNAU Zn citrate and commercial Zn EDTA @ 0.75 and 1.5 kg Zn ha^{-1}, 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 statistical design followed for field experiment was Randomized Block Design (RBD) with three replications.

Soil Test Crop Response (STCR) based NPK fertilizer dose for Maize hybrid for a yield target of 9 t ha^{-1} was 259, 96 and 38 kg ha^{-1}N, P_2O_5 and K_2O respectively. NPK fertilizers and $FeSO_4$@ 50 kg ha^{-1} to correct the available Fe deficiency in the experimental soil were applied to all treatments. Necessary crop protection measures were taken up. Observations on yield attributes such as cob length, number of grains cob^{-1}, 100 grain weight, grain and stover yield were recorded. Post harvest soil samples collected from field experiment were analyzed for DTPA-Zn. Economics of different treatments viz., net income and B:C ratio were worked out. The data recorded 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 given in Table 1. The experimental soil belongs to Periyanaickenpalayam series which comes under the taxonomic classification fine, montmorillonitic, isohyperthermic, calcareous TypicHaplustert. The soil texture was clay loam. The experimental soil was alkaline in reaction (8.07) with permissible amount of soluble salts (0.24 dS m^{-1}). The soil was calcareous and had low organic carbon content (4.79 g kg^{-1}). The available N, P and K content of the soil was low (134 kg ha^{-1}), medium (16.7 kg ha^{-1}) and high (657 kg ha^{-1}) respectively. Regarding micronutrients, 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}).

Table 1. Characteristics of Initial Soil Sample.

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

A. Yield attributes and yield of maize

Significantly highest cob length of 21.2 cm was registered in the treatment foliar spray of 0.5 % TNAU Zn EDTA (T_{10}) which remained on par with the 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). Lowest cob length of 15.9 cm was noticed in control (NPK alone -T_1). With regard to no. of grains per cob, significantly highest value (269) was observed in the treatment foliar spray of 0.5 % TNAU Zn EDTA (T_{10}). Significantly lowest value (224) was registered in control (NPK alone) 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). Hundred grain weight values varied from 36.1 to 41.2g (Table 2). Though the variation observed among the treatments was not significant, numerically higher value was noticed in the treatment foliar spray of 0.5 % TNAU Zn EDTA (T_{10}).

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 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). 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. Foliar spray of 0.5% 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 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).

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).

Table 2: Effect of Zn formulations on yield attributes and yield of maize.

Treatments	Cob length (cm)	No. of grains/cob	100 grain weight (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1-Control (NPK alone)	15.9	224	36.1	5867	10088
T_2-7.5 kg Zn ha^{-1} as $ZnSO_4$	18.1	245	40.3	6423	11198
T_3-0.75 kg Zn ha^{-1} as TNAU Zn EDTA	19.1	251	40.6	6547	11483
T_4-1.5 kg Zn ha^{-1} as TNAU Zn EDTA	20.8	265	41.1	6985	12352
T_5-0.75 kg Zn ha^{-1} as TNAU Zn citrate	16.5	233	39.8	5937	10415
T_6-1.5 kg Zn ha^{-1} as TNAU Zn citrate	18.8	249	40.5	6452	11408
T_7-0.75 kg Zn ha^{-1} as commercial Zn EDTA	16.2	231	39.5	5910	10355
T_8-1.5 kg Zn ha^{-1} as commercial Zn EDTA	17.5	241	39.9	6182	10662
T_9-Foliar spray of 0.5 % $ZnSO_4$*	17.8	243	40.1	6377	11067
T_{10}-Foliar spray of 0.5 % TNAU Zn EDTA *	21.2	269	41.2	7158	12741
T_{11}-Foliar spray of 0.5 % TNAU Zn citrate*	20.2	262	41.1	6962	12115
T_{12}-Foliar spray of 0.5 % commercial Zn EDTA*	19.9	259	40.8	6777	12052
SEd	0.8	7	1.1	287	504
CD (P=0.05)	1.7	15	NS	595	1044

*thrice on 30, 40 and 50 DAS

Zn application significantly enhanced the yield and yield contributing parameters of maize crop (Khalid *et al*., 2013; Babu and Malathi, 2019; Hisham *et al*., 2021). Need for Zn fertilization to maize crop grown in soils with low Zn status to achieve the targeted yield level was already documented by Babu *et al*., (2019). The results revealed that when compared to soil application, foliar application performed better. This might be due to the calcareous nature of the experimental soil. Foliar application of chelated fertilizers is often more effective than soil application (Guodong Liu *et al*., 2015). Small amount of foliar applied Zn, Fe and Mn significantly increased the yield of crops (Wissuwa *et al*., 2008). Foliar nutrition is an option where nutrient deficiencies cannot be corrected by soil application of nutrients (Cakmak, 2008).

Among the different formulations, chelated Zn fertilizers registered higher yield when compared to $ZnSO_4$. Foliar spray of Zn EDTA gave a higher grain yield of spring barley than Zn sulphate (MacNaeidhe and Fleming, 1988). 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 was observed by Khalid *et al*. (2013). Syed *et al*. (2016) and Kulhare *et al*. (2017) also reported similar results. Panda and Doddamani (2018) observed the better performance of Zn EDTA as compared to $ZnSO_4.7H_2O$ in bajra. Ortega-Blu and Molina-Roco (2007) reported higher corn dry matter with Zn EDTA as compared to $ZnSO_4$.

The increase in both grain and straw yield with application of Zn-EDTA might be due to the relatively higher Zn uptake compared to $ZnSO_4$ application. This is in line 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. Naik and Das (2008) observed that Zn mobilisation efficiency was higher with Zn-EDTA than with $ZnSO_4$ for Zn uptake by grain and straw.

B. Post harvest soil Zn status

Regarding post harvest soil Zn status, soil application of 7.5 kg Zn ha^{-1} as $ZnSO_4$ (T_2) recorded the significantly highest value of 0.99 mg kg^{-1} (Table 3). This might be due to the addition of 5 times higher dose of $ZnSO_4$ as compared to Zn-EDTA and Zn citrate. This is in line with the results reported by Keerthana *et al*. (2019). Soil application of 1.5 kg Zn ha^{-1} as TNAU Zn EDTA, commercial Zn EDTA and TNAU Zn citrate registered comparable post harvest soil Zn values. The lowest post harvest soil Zn of 0.48 mg kg^{-1} was observed in control (NPK alone -T_1) which remained on par with the foliar Zn applied treatments.

C. Economics of Zn formulations

The highest B:C ratio of 2.55 was noticed in the treatment foliar spray of 0.5% TNAU Zn EDTA (T_{10}) which was followed by foliar spray of 0.5% TNAU Zn citrate (T_{11}) (2.54) (Table 3). Net income was highest (Rs. 76,375/-) in the treatment foliar spray of 0.5% TNAU Zn EDTA (T_{10}) followed by foliar spray of 0.5% TNAU Zn citrate (T_{11})(Rs.73,872/-).

Table 3. Effect of Zn formulations on post harvest soil Zn status and economics in maize.

Treatments	Soil Zn (mg kg^{-1})	Net income (Rs.)	B : C ratio
T_1-Control (NPK alone)	0.48	57772	2.30
T_2-7.5 kg Zn ha^{-1} as $ZnSO_4$	0.99	64735	2.36
T_3-0.75 kg Zn ha^{-1} as TNAU Zn EDTA	0.62	64756	2.30
T_4-1.5 kg Zn ha^{-1} as TNAU Zn EDTA	0.69	68103	2.25
T_5-0.75 kg Zn ha^{-1} as TNAU Zn citrate	0.59	55958	2.17
T_6-1.5 kg Zn ha^{-1} as TNAU Zn citrate	0.67	62508	2.23
T_7-0.75 kg Zn ha^{-1} as commercial Zn EDTA	0.60	52112	2.02
T_8-1.5 kg Zn ha^{-1} as commercial Zn EDTA	0.68	50529	1.88
T_9-Foliar spray of 0.5 % $ZnSO_4$*	0.49	65031	2.40
T_{10}-Foliar spray of 0.5 % TNAU Zn EDTA*	0.51	76375	2.55
T_{11}-Foliar spray of 0.5 % TNAU Zn citrate*	0.50	73872	2.54
T_{12}-Foliar spray of 0.5 % commercial Zn EDTA*	0.52	68439	2.35
SEd	0.03	-	-
CD (P=0.05)	0.06	-	-

*thrice on 30, 40 and 50 DAS

CONCLUSION

Foliar application of Zn fertilizers registered higher yield than soil application which might be due to the calcareous nature of the experimental soil. The treatment foliar spray of 0.5% TNAU Zn EDTA (T_{10}) recorded highest yield attributes (cob length, no. of grains /cob, 100 grain weight), grain and stover yield, net income and B:C ratio which was comparable with foliar spray of 0.5% TNAU Zn citrate (T_{11}).

FUTURE SCOPE

In future, the mechanism by which nutrients from soil and foliar applied chelated fertilizers are taken up by the crops need to be explored.

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Conflict of interest: Nil

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