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Response of Maize to Soil Applied Zinc Fertilizer under Varying Available Zinc Status of Soil

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Abstract

Among micronutrients, zinc is recognized as one of the main limiting factors of growth and yield of maize crop. To study the response of different levels of Zn as $ZnSO_4$ on growth and yield of hybrid maize (NK 6240), field experiments were conducted at farmers' fields in Erode district with varying initial soil Zn status. The treatment consisted of six levels of Zn (0 1.25, 2.50, 5.00, 7.50 and 10.0 kg ha^{-1}) replicated four times in a Randomized block design. The results revealed that the highest plant height, thousand grain weight, cob yield, stover and grain yield were recorded in the treatment with 7.50 kg Zn ha^{-1} in location 1 having low initial Zn status, 5.00 kg Zn ha^{-1} in locations 2 and 3 having medium and high initial Zn status respectively. Thus, the highest grain yields of 7.42, 7.45 and 7.56 t ha^{-1} were obtained with application of 7.50, and 5.00 kg Zn ha^{-1} in location 1 and location 2 and 3 respectively, the yield increase being 39.08, 33.15 and 28.84% over NPK control. The results of the study clearly indicate that there was a significant response to the applied Zn in soil having severe Zn deficiency, while the soil having adequate Zn status also showed comparatively better and there was a decline or no response to the applied Zn at higher levels in soil having high zinc status.

Keywords: Growth, Low Zinc Status, Maize, Zinc, Yield Attributes

1. Introduction

Zinc is one of the most important micronutrients for many crop plants such as rice, maize and wheat, or soybean, which all are worldwide cultivated. It is a trace element needed in small but in critical concentrations. If the amount available is not adequate, plants will suffer from physiological stress brought about by the dysfunction of several enzyme systems and other metabolic functions in which Zn plays a part[1]. Zinc deficiency has increased from 44% to 48%, and is expected to further increase up to 63% by 2025 in India. Most of the marginal soils are showing higher response to added zinc[2]. In some parts of Tamil Nadu, Zn deficiency has increased from 36% in 1980 to 73.8% in 2008 because of extensive use of multi-micronutrient mixtures, mainly through foliar sprays which left little residual effect in soils compared to other states using ZnS04. Zinc deficiency continues to be one of the key factors in determining cereal (rice, maize) production in several parts of the country[3].

Maize (Zea mays L.) is the third most important cereal crop of world as well as India after wheat and rice. Maize is a miracle crop called "Queen of Cereals" and is grown in more than 130 countries. In India, maize is cultivated in 8.11 m ha with a production of 19.77 m t and the average yield is 2.44 t / ha [4]. In Tamil Nadu, maize is cultivated in an area of 0.18 m ha with a production of 0.29 m t and an average productivity of 1.55 t/ha [5]. By 2020, the requirement of maize for various sectors will be around 100 m t, of which poultry sector needs 31 m t. Every part of the maize plant has economic value of which the grain, leaves, stalk, tassel and cob can all be used to produce a large variety of food and non food production. Hence, it is a challenging task for us to increase the maize production from the present level[6].

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The deficiency of micronutrients may emerge when the supply of micronutrients to the soil is less compared to removal through crop harvest which in turn limits crop productivity[7]. In severe deficiency situations, the yield loss could reach as high as 100% due to omission of micronutrients in the cropping system. Yield loss with omission of Zn fertilization was reported as 10% in India[7]. Zinc deficiency is usually corrected by application of zinc sulfate. Response to applied zinc for better growth and yield of several important field crops has been reported from many countries[8,9]. The response of crop plants to the deficiency or sufficiency of specific nutrients has helped to generate information on the critical limits of each of the elements. Soil analysis indicated that Zn deficiency is widespread in India. Crops grown in fields having available nutrient status below the critical limits significantly responded to the application of Zn. This implies that balanced plant nutrition is essential for sustained increase in the productivity. Keeping in view of the importance of zinc nutrition for maize, the objective was framed to study the response of maize to zinc fertilizer application related to the available zinc status of soil.

2. Materials and Methods

2.1 Soil Sampling

Totally 55 representative soil samples were collected from the surface layer (0-15 cm) based on GPS soil survey in the study locations, Erode district, Tamil Nadu before the commencement of the experiment using stainless steel materials and a composite sample was prepared. These samples were air-dried, ground in a wooden mortar, passed through 2mm sieve and stored in plastic bags for analysis.

2.2 Soil Analysis

Available zinc status in collected soil samples was estimated by DTPA method proposed by Lindsay and Norvell[10]. Based on the available status of Zn (DTPA- Zn), three groups were formed with the soil below 1.20 mg kg^{-1} DTPA-Zn, soil having 1.20^{-1}.50 mg kg^{-1} DTPA-Zn and soil with above 1.50 mg kg^{-1} DTPA-Zn. The soils were analyzed for the determination of the electrical conductivity in 1:2.5 soil-water extract by conductivity meter, the pH in 1:2.5 soil-water suspension using pH meter. The Cation Exchange Capacity (CEC) of the soils was determined using Neutral N NH_4OAc [11]. The Organic carbon content of the soils was determined by chromic acid wet digestion method[12]. The textural classes of soil were determined by most accurate International pipette method[13].

2.3 Field Experiment

Field experiments were conducted to study the response of zinc fertilizer on maize crop grown on different soils having varying zinc status. Based on the available DTPA – Zn (three groups), one location each in one group has been selected for the experiment. The study was conducted at 3 locations (1x3= 3 locations) with six levels of Zn as $ZnSO_4$ (0, 1.25, 2.50, 5.00, 7.50, 10.0 kg Zn ha^{-1}). A uniform application of NPK was given as per recommendation (250:75:75 NPK kg ha^{-1}) and the treatments were replicated four times at Randomized Block Design with maize crop (NK 6240 hybrid). As basal dose 25% of nitrogen, full dose of phosphorus and potassium were applied at the time of sowing, while the remaining 50% nitrogen was given at vegetative stage and again 25% at the tasselling stage of crop. At Tasselling (55-65 Days after planting) and harvest (110 Days after planting), five plants were collected in each plot randomly to record plant height. Yield parameters like 1000 grain weight, cob yield, grain yield, and stover yield were recorded plot wise and expressed as tonnes per hectare.

3. Results and Discussion

3.1 Soil Properties

The soil samples used in this study varied in their soil properties (Table 1.), where the pH of all the three locations were slightly alkaline in reaction and ranged from 7.19 to7.32. The EC of the soil ranged between 0.14 and 0.39 (d S m^{-1}) which is normal, indicating that the soil is free from salinity. Based on the soil test data, all the soil samples were found low in organic carbon which fluctuated between 0.73 and 5.21 g kg^{-1}. In addition to the above properties, cation exchange capacity in surface soils ranged from 11.7 to17.2 (c mol (p+) kg^{-1}) and the highest value was obtained in location 1 (17.2 c mol (p+) kg^{-1}) and the lowest in location 3 (11.7 c mol (p+) kg^{-1}). All the experimental soils are sandy loam in texture. In comparison with the critical limit of Zinc (Zn) as 1.20 mg kg^{-1} fixed for Tamil Nadu soil, the available Zn in soils (0.46 – 1.78 mg kg^{-1}) showed that the values were very low in location 1, low in location 2 , medium in location 3 and high in location 4 respectively.

3.2 Plant Height

Results showed that the height of maize plant both at tasselling and harvest stages was significantly influenced by application of different levels of Zn in a varied available Zn status of soil. The maximum plant height was 141.6 and 255.1 cm at tasselling and harvest stages respectively with 7.5 kg Zn ha^{-1} application at the location 1 followed by 10.0 kg Zn ha^{-1} at the same location with 135.1 and 238.4 cm at tasselling and harvest stages respectively, while compared to NPK alone treatment (Table 2). Eventhough the fertilizer application was similar at all the locations, the response trend differed among locations. The Zn application at 5.0 kg ha^{-1} in location 2 gave the highest plant height (139.1 cm) but comparatively lower than that in the location 1. Similarly, at the location 3 there was a slight numerical increase in the plant height but the treatment differences were non significant. Thus the growth of plant varied between the locations due to the added zinc to the maize crop as well as the initial soil Zn status indicating that there was reduction in plant height due to Zn application especially in soil having high Zn status. The percent increase in the plant height was 19.07%, 11.72% and 8.66% at tasselling stage and similarly, at harvest the percent increase was 18.11%, 9.78% and 7.15% for Zn treatments 7.50 kg for location 1 and 5.00 kg for locations 2 and 3 respectively over control (NPK alone). The increase in plant height may be due to the balanced application of Zn along with NPK fertilizer, as many researchers state that zinc is involved in a number of physiological processes of plant growth and metabolism[14–17]. Zinc is required for the synthesis of tryptophan[18, 19], which is a precursor of IAA, this metal also has an active role in the production of auxin, an essential growth hormone[20,21].

Table 1. Soil properties of experimental location

Soil properties	Location 1	Location 2	Location 3
Soil pH	7.32(±0.018)	7.32(±0.012)	7.19(±0.012)
EC (d S m^{-1})	0.39(±0.018)	0.33(±0.012)	0.14(±0.015)
Organic carbon (g kg^{-1})	2.63(±0.012)	5.21(±0.018)	0.73(±0.021)
CEC (c mol(p+) kg^{-1})	17.2(±0.503)	13.2(±0.233)	11.7(±0.240)
Textural Class	Sandy loam	Sandy loam	Sandy loam
Available Zn (mg kg^{-1})	0.87(±0.026)	1.22(±0.028)	1.78(±0.022)

3.3 Yield Components

The results of 1000 grain weight presented in the Table 3 showed that in general the different levels of Zn significantly influenced the 1000 grain weight in all the locations. The maximum weight of 295 gm was noticed at location 1 with 7.5 kg Zn ha^{-1} followed by 284 gm for 5.0 kg Zn ha^{-1} at the same location and the lowest was recorded in control (NPK alone treatment). Similarly at the location 2 the maximum weight of 294 gm was observed with 5.0 kg Zn ha^{-1} application but comparatively low to location 1 whereas at the location 3 still reduced weights were noticed and showed slight numerical increases for the application of Zn. The percent increase of 1000 grain weight was 16.27, 12.24 and 8.97% for Zn treatments 7.50 kg for location 1 and 5.00 kg for locations 2 and 3 respectively over control. These findings are closely related with the results reported by Ziaeyan and Rajaie[22] where Zn application increased thousand grain weight in corn plants. Yilmaz et al.[23] reported that following Zn fertilization, thousand grain weight showed an increase in wheat plants. Hemantaranjan and Grag[24] observed that optimum utilization of Zn significantly increased thousand grain weight in wheat. The cob yield data furnished in the Table 3 revealed that there was a

Table 2. Effect of Zn application on plant height at tasselling and harvest stage of maize crop

Zn levels kg ha^{-1}	Plant height at tasselling stage (cm)			Plant height at harvest stage (cm)		
	Location 1	Location 2	Location 3	Location 1	Location 2	Location 3
0	114.6(±4.0)d	122.8(±3.4)b	123.5(±3.1)a	208.9(±2.3)d	221.4(±5.1)c	228.6(±3.5)b
1.25 Zn	120.8(±2.9)cd	127.5(±3.3)ab	128.1(±3.3)a	218.4(±2.2)d	228.6(±4.3)bc	232.5(±3.6)ab
2.50 Zn	124.7(±2.2)bcd	133.1(±4.3)ab	134.1(±3.3)a	232.1(±2.8)c	238.1(±4.3)ab	244.1(±5.0)a
5.00 Zn	129.6(±2.5)abc	139.1(±4.7)a	135.2(±3.3)a	237.9(±2.7)bc	245.4(±5.3)a	246.2(±5.7)a
7.50 Zn	141.6(±2.3)a	134.5(±5.0)ab	132.5(±3.4)a	255.1(±2.4)a	243.1(±5.4)a	239.2(±5.3)ab
10.0 Zn	135.1(±2.4)ab	132.2(±4.9)ab	130.8(±3.1)a	238.4(±2.1)ab	240.6(±5.1)ab	235.1(±4.6)ab

Table 3. Effect of Zn application on 1000 grain weight and cob yield of maize crop

Zn levels kg ha^{-1}	1000 grain weight (gm)			Cob yield (t ha^{-1})		
	Location 1	Location 2	Location 3	Location 1	Location 2	Location 3
0	247(±9.2)d	258(±6.7)d	264(±5.2)d	6.58(±0.4)e	7.90(±0.5)d	8.15(±0.7)c
1.25 Zn	261(±7.9)cd	267 (±8.1)cd	272(±4.5)cd	8.51(±0.3)d	8.62(±0.4)c	9.75(±0.4)b
2.50 Zn	271(±10.3)bc	276(±8.8)bc	288(±4.0)ab	9.28(±0.2)c	9.10(±0.3)b	10.78(±0.3)a
5.00 Zn	284(±8.9)ab	294(±6.7)a	290(±3.2)a	10.45(±0.4)b	10.87(±0.3)a	10.91(±0.3)a
7.50 Zn	295(±8.5)a	290(±6.7)ab	284(±4.0)abc	11.29(±0.4)a	10.52(±0.4)a	9.97(±0.4)b
10.0 Zn	281(±8.6)b	282(±6.7)ab	274(±4.2)bcd	10.48(±0.4)b	8.98(±0.3)b	8.52(±0.5)c

Table 4. Effect of Zn application on stover yield and grain yield of maize crop

Zn levels kg ha^{-1}	Stover yield (t ha^{-1})			Grain yield (t ha^{-1})		
	Location 1	Location 2	Location 3	Location 1	Location 2	Location 3
0	9.69(±0.2)e	10.42(±0.3)f	10.75(±0.3)e	4.52(±0.2)f	4.98(±0.2)e	5.38(±0.1)e
1.25 Zn	10.59(±0.3)d	11.35(±0.3)d	11.64(±0.4)d	5.08(±0.2)e	5.45(±0.2)d	6.83(±0.2)b
2.50 Zn	11.01(±0.3)c	12.12(±0.4)b	12.52(±0.2)b	5.89(±0.3)d	6.78(±0.3)b	7.38(±0.3)a
5.00 Zn	11.74(±0.4)b	12.68(±0.2)a	12.71(±0.3)a	6.58(±0.3)c	7.45(±0.3)a	7.56(±0.4)a
7.50 Zn	12.18(±0.4)a	11.89(±0.3)c	12.02(±0.3)c	7.42(±0.3)a	7.20(±0.3)a	6.97(±0.2)b
10.0 Zn	11.79(±0.4)b	10.92(±0.3)e	10.78(±0.3)e	6.84(±0.2)b	6.38(±0.3)c	6.05(±0.3)d

significant difference among the treatments and similar to above parameters, a maximum value of 11.29 t ha^{-1} was found at location 1 with 7.5 kg Zn ha^{-1} followed by 10.48 t ha^{-1} for 10.0 kg Zn ha^{-1}, while the lowest recorded in control treatment (NPK alone) and the percent increase was 41.72, 27.32 and 25.30% for Zn treatments 7.50 kg for location 1 and 5.00 kg for locations 2 and 3 respectively over control. The location 2 and 3 showed a statistically significant result but decreasing trend was observed beyond optimal of Zn application in respect of cob yield compared to location 1. This result clearly shows there was a spectacular response for applied Zn when the Zn status was below critical limit. Studies have shown that application of Zn through $ZnSO_4$ to maize (*Zea mays*) recorded significantly higher growth parameters and yield attributes and recording significantly higher tillers/plant, branches/plant and capsules/plant of crop[25]. Regarding the yields of stover and grains of maize (Table.4), both the parameters showed significant results to applied Zn and at the location 1, the maximum yield of 12.18 t ha^{-1} and 7.42 t ha^{-1} of stover and grains respectively were recorded. Here also the location 2 and 3 showed a reduction n the yield at 7.50 kg Zn ha^{-1} but at 5.0 Zn ha^{-1} the yield was higher compared to location 1 and thereafter the response to added Zn shows a declining trend, proving that there was a positive response to applied Zn fertilizer when the soil is deficient in available zinc. The percent increase was 20.44, 17.82 and 15.42% for stover yield and 39.08, 33.15 and 28.84% for grain yield for Zn treatments 7.50 kg for location 1 and 5.00 kg for locations 2 and 3 respectively over control. Studies have proven that similar increases due to Zn application in dry matter and grain yields in different crops[26]. The yield increase as a result of Zn fertilization was also reported by many workers[27,28]. Zeidan et al.[29] reported that application of Zn significantly increased grain yield and yield components of wheat. Similarly, Maralian[30] found that application of Zn increased seed yield and quality of wheat compared to NPK control.

4. Conclusion

Application of Zinc sulphate in zinc deficient soil has shown improvement in respect of growth and yield of maize. The percent increase was also higher at location 1 compared to location 2 and 3 in all aspects. However, compared to location 1 with low Zn status and location 2 with medium Zn status, the location 3 with adequate zinc showed statistically significant result for applied Zn but there is reduction in the growth and yield parameter beyond optimum level. So, from this study it is clear that, there is a response for Zn application to the soil having adverse Zn deficiency and sameway decline in the response also occurs when Zn application exceeds the optimum level due to toxic effect or other reasons. Similarly, the percent increase in growth and yield was higher when zinc is applied in combination with NPK when compared to control (only NPK). Hence, balanced fertilization, where NPK fertilizer should be applied along with Zn in a Zn deficient soil, is essential for increasing productivity of maize and in turn to alleviate Zn deficiency in soil, plant, animal and human continuum.

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6. References

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