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Zinc and Organo-Mineral Fertilization Effects on Biomass Production in Maize (*Zea mays*) Grown on Acid Sand Alfisol (Typic Paleudalf)

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Abstract: This study was conducted to determine the effect of Cow Dung (manure) alone (CD), zinc sulphate alone, $ZnSO_4$ (23% Zn) and their organo-mineral combination (CD+$ZnSO_4$) on the performance of maize (*Zea mays*) at the Teaching and Research Farm of the University of Ado-Ekiti. The fertilizer treatments consisted of 0, 15 and 30 mg Zn kg^{-1} soil to give 9 treatment combinations replicated three times in a Complete Randomized Design (CRD). Growth parameters were measured at 7, 14, 21 and 28 days of growth while shoot weight and Zn uptake by the crop were determined at 28 days after planting. The result indicated that application of 30 mg Zn kg^{-1}soil and organo-mineral combination (Cow dung+$ZnSO_4$) significantly ($p<0.05$) gave the highest plant shoot biomass (7.11 g pot^{-1}) base on dry shoot weight. Also application of CD also led to the highest Zn uptake.

Key words: Maize, cow dung manure, zinc fertilizer, organo-mineral, uptake

INTRODUCTION

Zinc in human nutrition has been overwhelming as it causes growth retardation coupled with delay in skeletal maturation. Improving human Zn nutrition would involve enhancing Zn concentrations in plant foods (WHO, 2005) and applications of Zn fertilizers could effectively increase Zn concentrations in edible portions of crops (Rengh *et al*., 1999). Zinc deficiency increases with time on a wide variety of tropical soils through the use of purified, highly concentrated fertilizers (Munkholm *et al*., 1993) and high yielding, more nutrient demanding improved crop cultivars. Maize is more sensitive to Zn supply than most other crops (Bukvie *et al*., 1999). Corrale ***et al.*** (1996) noted the yield advantages accruing from the application of inorganic fertilizers but cautioned on the negative influence of their cost and availability resulting in the popularity of organic materials as means of supplementing native soil fertility in tropical areas. It has been noted that cow dung manure improves soil structure, water holding capacity, aeration and drainage besides containing high levels of Fe, Mn and Zn (Adediran *et al*., 1996). Nevertheless, observed that combined use of organic and inorganic fertilizers is the best means of augmenting available nutrient contents of tropical soils. Organo-minerals reduce the acidification and increased removal of nutrients other than the one being supplied. The research was established to compare the effectiveness of Cow Dung manure (CD), $ZnSO_4$ and their Combination (CD+$ZnSO_4$) as Zn fertilizer sources for the growth as well as Zn nutrition of maize.

MATERIALS AND METHODS

Trial sites: The study was conducted at the Teaching and Research Farm, University of Ado-Ekiti between May and July 2006. Ado Ekiti is located on latitude 7.3o N and longitude 5.3° E. The area has a bimodal rainfall with mean annual rainfall of 1367mm and a daily temperature of 27°C. The area falls within the high forest zone where the rich tropical forests once thrived. The region has a tropical humid climate with distinct wet and dry seasons. The wet season is from late March to October with little dry season in July and August.

Soil preparation and analysis: Prior to planting, soil samples were collected air-dried in the laboratory, ground and sieved through a 2 mm sieve. Particle-size distribution was determined by the hydrometer method (Bouyoucos, 1951). Soil pH was measured using the pH meter at 1:1 soil to water ratio. The percentage organic carbon was determined by the Walkey Black wet oxidation method (Walkley and Black, 1934) while percent total Nitrogen (N) was determined by the micro-kjeldahl technique (Jackson, 1962) The present organic matter was estimated by multiplying the percent organic carbon with a factor of

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1.724. Available P was extracted by the Bray/method and determined colorimetrically (Bray and Kurtz, 1945). Exchangeable bases were displaced by NH_4+from neutral/NH_4OAC solution as describe by Jackson (1958). Calcium (Ca) and Magnesium (Mg) were determined by the Atomic Absorption Spectrophotometer (AAS) and potassium (K) and sodium (Na) were determined by flame emission photometry. Cation Exchange Capacity (CEC) 3was determined by the neutral/NH_4OAC saturation method. Base saturation was calculated with reference to the NH_4OAC-CEC. Exchangeable acidity was extracted with IMKCL and determined by titration with NaOH solution.

Greenhouse experiment: The Zn fertilizer materials were thoroughly mixed with 5 kg of the soils, moistened to 60% FC and allowed to equilibrate for 5 days prior to planting of three seeds per pot.

The experiments involved the split-plot arrangement in complete randomized design with treatments replicated three times. The Zn fertilizer sources (Cow dung, $ZnSO_4$ and $ZnSO_4$+Cow dung) formed the main treatment while the Zn application levels (0, 15 and 30 mg Zn kg) formed the sub-treatment. Nitrogen and Potassium were applied uniformly to all pots at the rate of 60 kg N ha^{-1} (using urea) and 30 kg K ha^{-1} (using muriate of potash, KCI).

Growth evaluation and analysis: Growth parameters (plant height, stem girth and leaf area) were measured from 1Week After Planting (WAP). At 28 days after planting, the maize plants were harvested and processing of the above ground plant biomass was done and shoots weights (fresh and dry) determined. Also Zn uptake by the test crop were determined after grinding the dried plant samples and wet digesting with a mixture of 25 mL of HNO_3, 5 mL of H_2SO_4 and 5 mL of $HClO_4$. Zn was read using atomic absorption spectrophotometer.

All statistical analyses were performed using the Statistical Analysis System (1985).

RESULTS AND DISCUSSION

Fertility evaluation: The physical and chemical properties of Soils used for Zn response studies are shown in Table 1.The pH of the soil was 6.6 which is weakly acid sand Alfisol (Typic Paleudalf. Organic C (8.30 g kg^{-1}), total N (0.8 g kg^{-1}), available P (8.77g kg^{-1}) and extractable Zn (0.092 cmol kg $^{-1}$). The total N values were less than the critical level of 1.5 g kg^{-1} (Enwenzor *et al*., 1979). The available p-values were less than the critical level of 10-16 mg kg^{-1} (Adeoye and Agboola, 1985). While exchangeable K values were above the critical level of 0.18-0.20 cmol kg^{-1} (Agboola and Obigbesan, 1974). However, Zn values were above the critical level of 0.003 cmol kg^{-1} (Osiname, 1972).

Table1: Physico-chemical properties of the soils and cow dung used

Soil properties	Soil value	Cow dung value
pH (H_2O) 1:1	5.68	
Total N (g kg^{-1})	0.80	0.59%
Available P (mg kg^{-1})	8.77	1.20%
Organic C (g kg^{-1})	8.30	
Exchangeable bases (cmol kg^{-1})		
Ca	1.30	
Mg	0.14	
K	0.25	
Na	0.84	
Exch. Acidity	0.21	
CEC (cmol kg^{-1})	2.74	
Zn (mg kg^{-1})	0.09	0.06
Clay (g kg^{-1})	188	
Silt (g kg^{-1})	480	
Sand (g kg^{-1})	332	
Texture:	Loamy	

Table 2: Effect of zinc fertilizer sources on plant height, stem girth and leaf area of maize

	Days after planting			
Treatment	7	14	21	28
Plant height (cm)				
Cow dung	20.2a	35.1a	50.3a	53.2a
$ZnSO_4$	22.1a	36.0a	39.1b	42.0b
CD + $ZnSO_4$	21.9a	36.0a	39.2b	50.7a
Stem girth (cm)				
Cow dung	0.90a	1.63a	1.67a	1.97a
$ZnSO_4$	0.81a	1.30a	1.45a	1.42b
CD + $ZnSO_4$	0.92a	1.40a	1.71a	1.78a
Leaf area (cm^2)				
Cow dung	17.1a	42.0a	52.5a	85.3a
$ZnSO_4$	20.2a	43.5a	48.6	70.1b
CD + $ZnSO_4$	16.8a	42.1a	59.5	79.2b

Means in each column for each factor followed by same alphabets do not differ significantly ($p<0.05$)

Table 3: Effect of zinc fertilizer levels on plant height, stem girth and leaf area of maize

Treatment levels	Days after planting			
mg Zn kg^{-1}	7	14	21	28
Plant height (cm)				
0	21.0a	35.3a	39.1c	413b
15	20.1a	37.9a	45.2b	48.1a
30	21.2a	40.0a	54.0a	54.7a
Stem girth (cm)				
0	0.90a	1.43a	1.47a	1.43a
15	0.91a	1.30a	1.45a	1.82b
30	0.92a	1.40a	1.71a	1.98a
Leaf area (cm^2)				
0	16.1a	40.9a	40.0a	61.3c
15	16.2a	53.5a	42.6a	80.1b
30	20.8a	62.1b	44.5a	93.2a

Means in each column for each factor followed by same alphabets do not differ significantly ($p<0.05$)

Table 2 and 3 indicated the effects of the Zn fertilizer sources and rates on maize growth. Plant height and stem girth increased with time almost reaching the peaks at 21 days after planting (Table 2). The plants were significantly ($p<0.05$) more vigorous in height and stem girth most especially for organic and organo-mineral combination. After 28 days of growth, mean height and stem girth were 53.20 cm and 1.9 cm. The fertilizer rates also influenced the growth of maize such that the untreated maize consistently gave low value such that at 28 days after planting 30 mg Zn. kg^{-1} gave 54.7, 1.98 and 93.2 cm^2 for plant height stem girth and leaf area, respectively. The tendency was such that the inorganic Zn fertilizer source ($ZnSO_4$) reduced plant growth while plants treated with either the organic manure or a mixture of cow dung and $ZnSO_4$ had almost the same values at the successive growth periods. Between 7 and 21 DAP, the three fertilizer types (Table 2) produced no significant difference ($p<0.05$) in leaf area but there was significantly different between the three fertilizer sources with cow dung manure having higher leaf area, (85.3 cm^2) than $ZnSO_4$(79.5cm^2) and organo-mineral fertilizer (70.1 cm^2), respectively. The fertilizer treatment (sources) had appreciable effect on fresh weight, dry shoot weight and Zn-uptake (Table 4) with maize planted to cow dung manure alone having the highest Zn uptake, this is as a result of the organic manure (cow dung) being a reservoir of nutrients and with ameliorative capacity (Ridder and Keulen, 1990). Also the organo-mineral combination (Cow dung + $ZnSO_4$) fertilizer mixture remarkably increased the uptake of Zn in maize plants.

The zero fertilizer application (Table 5) consistently recorded the least fresh shoot weight and dry shoot weight values of 3.20 and 4.0 g pot^{-1}, respectively while those treated with 30 mg kg^{-1} soil had the highest values of 6.10 g pot^{-1} and 7.11 g pot^{-1}, respectively. Treatment with 30 mg Zn/kg soil also led to greater amount of Zn uptake (1.18 mg Zn kg^{-1}) as against 0.41 mg Zn kg^{-1} for the untreated maize plants while 0.80 mg Zn pot^{-1} for the plants treated with 15 mg Zn kg^{-1} soil was not significantly different from either of the other.

The remarkable differences in vigor and biomass production of maize grown were attributed to the physico-chemical properties of the soils. This condition facilitated the release of nutrients for plant growth. Soil fertility can be maintained with the use of organic manures alone or in combination with inorganic fertilizers. The use of organic manure in combination with inorganic fertilizers serves to reduce the negative effects of inorganic fertilizers, particularly in respect of acidification and increased removal of nutrients other than the one supplied by the fertilizer (Ridder and Keulen, 1990). Thus, the fortification of CD with $ZnSO_4$, in this study, could have directly reduced the negative effects of and improved the efficiency of $ZnSO_4$ but had no negative effect on the efficiency of CD. The significant reduction of the effects of sources of Zn fertilizers on the vigor and shoot weight of maize should have been due to the toxicity effects of high concentrations of Zn in the soil, Li *et al.* (2003) similarly attributed the reduction in plant biomass as Zn addition was made under low P conditions to Zn toxicity (Vanlawe *et al.*, 2002). Also reported that application of urea-fortified organic materials significantly increased dry matter accumulation of maize Stover in Zaria (Guinea Savanna zone), Nigeria. The fact that maize plants performed best at 30 mg Zn kg^{-1} is indicative of possible positive effect of Zn fertilizer application. This was evidenced by uptake of the nutrient elements by maize plants after 28 DAP Apart from containing 0.02% Zn, the organic manure had reasonably high proportions of other nutrient elements (2.30% N and 0.47% K) (Table 1). This is an indication that for every gram addition of Zn through CD, about 27.5 g of P is also added.

Table 4: Effect of zinc fertilizer sources on biomass yield and Zn uptake of maize

Treatment mgZnkg^{-1}	Fresh shoot g pot^{-1}	Dry shoot g pot^{-1}	Zn uptake mgZn pot^{-1}
Cow dung	45.5a	6.52a	0.90a
$ZnSO_4$	31.0c	3.81b	0.61b
CD+$ZnSO_4$	51.3b	6.10a	0.78a

Means in each column followed by same alphabets do not differ significantly ($p<0.05$)

Table 5: Effect of zinc fertilizer application levels on biomass yield and Zn uptake of maize

Treatment (mg Zn kg^{-1})	Fresh shoot g pot^{-1}	Dry shoot g pot^{-1}	Zn Uptake mg Zn pot^{-1}
0	3.20a	4.00a	0.41a
15	4.91a	5.51a	0.80a
30	6.10a	7.11a	1.18a

Means in each column followed by same alphabets do not differ significantly ($p<0.05$)

CONCLUSION

In conclusion therefore, combined use of organic and mineral fertilizers fortified cow dung is a good antidote for increasing Zn that may result in deficiency or toxicity in crop plants.

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