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Scientific Research

Effect of Cu and Zn on Maize (*Zea mays* L.) Yield and Nutrient Uptake in Coastal Plain Sand Derived Soils of Southeastern Nigeria

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Abstract

Laboratory, greenhouse and field studies were undertaken to investigate the status of Cu and Zn and to find out whether the addition of these nutrient elements in soils would increase maize grains and yield components and also, remediate their constraints in coastal plain sand derived soil of southeastern Nigeria, for optimization of maize (*Zea mays* L.) yields. Dry matter yields, plant concentrations, plant uptake, and maize grain yields were used to evaluate the effects of Cu and Zn levels. In both the greenhouse and field experiments, hydrated Cu and Zn sulphate fertilizers were applied to the soils in separate experiments at seven levels (0, 2, 4, 6, 8, 10 and 12 kg·ha^{-1}) for Cu and Zn respectively. The recommended N, P, and K at rates of 120, 60, 30 kg·ha^{-1}, respectively, were also used as basal application. The results showed the status of available Cu and Zn by 0.1 N HCl was found to be low in the soil. The application of Cu and Zn into the soils significantly ($P < 0.05$) increased maize dry matter production, concentration, uptake and grain yields. The estimated optimum rates for Cu and Zn under greenhouse environments were established at 10 kg·Cu·ha^{-1} and 8 kg·Zn·ha^{-1}, respectively. Maximum uptake and grain yields in maize were also established at 10 kg·Cu·ha^{-1} and 8 kg·Zn·ha^{-1}, respectively. However, maize response curve showed that for optimum grain yield, concentration for Cu was determined to be 10 mg·kg^{-1}, while for Zn it was 8 mg·kg^{-1}. The current study showed that though the soils have a severe Cu and Zn deficiency, which could be due to their strong sorption capacity and nutrients mining due to intensive and continuous cropping, maize production can still be increased considerably in this soil and other similar soils in the same agro-ecological zone within a coastal plain sand derived soil by applying Cu and Zn at rates of 10 kg·Cu·ha^{-1} and 8 kg·Zn·ha^{-1}, respectively.

Keywords

Cu, Zn, Maize, Yield, Nutrient Uptake, Coastal Plain Sand and Acid Sands

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1. Introduction

Maize (*Zea mays* L.) is one of the most important high value cereals crops in many households in Nigeria [1] [2]. The crop is widely cultivated in soils of Nigeria, including the coastal plain sands, parent material of soils of southeastern Nigeria [3] [4], which is highly weathered, predominantly lateritic with frequently low in exchangeable bases and cation exchange capacity [5]. The soils are low in organic matter content and mostly acidic in reaction [6], and leaching due to high rainfalls regimes couple with low activity characteristics of the clay fraction and in fact sandy nature of the soils [4], and almost deficient/low in major and minor nutrient elements specifically Cu and Zn [7] [8], and the availability of these nutrient elements to maize crop is conditioned by these characteristics of the soil under review. Generally, micronutrient-deficient soils do not support optimum crop yields because plant growth becomes retarded by the deficiency, leading to low yields [4] [8] [9].

The application of Cu and Zn fertilizers to maize crop not only enhances its production, but also increases tissue content and cures these nutrient deficiency problems in human beings. With intensive and continuous cropping, arable soils have been depleted in the essential micronutrient elements especially, Cu and Zn and nutrient availability is further aggravated in acid sands of Southeastern Nigeria.

The approaches that have been used to replenish these micronutrients in southeastern Nigeria soils include crop rotation, manure application, and the use of crop residues; however, such methods and materials do not optimize crop yields due to the insufficient micronutrients supplied by these materials. However, soluble sulphate of copper and zinc fertilizers are some other sources of micronutrients that can be used to replenish these micronutrients in the soils but, due to lack of information and high prices of these nutrients and of course, low agricultural-based incomes, only a few researchers who have access, use these salts and in most cases they use very low rates with NPK fertilizers [9]. Currently, it is possible for most small-income farmers who engaged in cultivating vegetables crops such as; okra, pepper and tomato and arable crops like; cassava, yam, coco-yam and maize, to use these soluble micronutrients which are less expensive and available. Field experiments conducted in coastal plain sand derived soils, using Cu and Zn on low micronutrients soils to increase the yield of maize production, have shown some crop response, but yield levels of maize obtained to date without them are however, relatively low. Similarly, [10] reported a yield range from 1.76 to 5.84 $t \cdot ha^{-1}$ from treatment rates of 2.5 kg $Cu \cdot ha^{-1}$ and 5 kg $Zn \cdot ha^{-1}$, however, the soils in southeastern Nigeria environment could support yields in excess of 5 $t \cdot ha^{-1}$ once the limiting nutrients are corrected [4] [11]. Currently, the status of available Cu and Zn in these soils is not known. Otherwise, the area has a favourable climate and the soils have good physical properties such as good tilt, moderately water-holding capacity, and good aeration [11] [12]. Such conditions are favourable for high yields of maize once any limiting nutrients are corrected [11]. It is hoped that the application of Cu and Zn will increase and sustain maize production; improve their content in the maize plant and grain which is essential for human and animal growth and development.

Current and past researches in other Nigerian soils and specifically savanna area of northern Nigeria, demonstrate that the application of Cu and Zn to maize crop has led to a significant increase in maize [3] [13] [14] and relative yields was closely correlated with extractable Cu and Zn [11] [15]. Although, the researches carried out in the savanna area of northern Nigeria showed responses of maize to Cu and Zn fertilization, but could also be studied in acid sands of southeastern Nigeria, with different soil characteristics and ecological zone, which need further improvement.

Keeping in view the importance of maize crop and nutritional role of Cu and Zn in increasing maize yield in coastal plain sands of southeastern Nigeria soils, greenhouse and field experiments were conducted with the main objectives to determine the status of copper and zinc in acid sands of Calabar soils, response of maize to Cu and Zn application and to determine the appropriate application levels of the two nutrient elements for increase and sustainable grain yields, yield components by maize under the prevailing conditions of coastal plain sands derived soils of southeastern Nigeria.

2. Materials and Methods

Soil samples were collected from a site that had not been treated with micronutrient fertilizers for the past 12 years for laboratory and greenhouse experiments. The site which has a high potential for dual seasons maize production was selected to represent coastal plain sand derived soil of southeastern, Nigeria [16]. The soil is also suitable for production of upland/swamp rice, okra, yam, citrus, oil palms, plantain/banana and recently some pineapple genotypes (GV. III), and some new cassava varieties from National Root Crop Research Institute, Umudike, Abia State Nigeria, have been introduced into the area because of their high market demands for local consumption and export.

2.1. Laboratory Study

Laboratory study was conducted to determine some physical and chemical properties and status of total and available Cu and Zn in the study area having been informed that these nutrients to be limiting micronutrients [3]. Before the study, eight core surface soil samples (0 - 20 cm) were taken each from the two experimental plots and these were bulked together to form two composite samples. The samples were analyzed for pH (H_2O) as described by Thomas [17], organic carbon was determined by wet oxidation [18], available P was determined by Bray I method [19], and total N was determined by Kjeldahl procedure of Bremner [20]. Effective cation exchange capacity and exchangeable cations were determined by the method described as in [21]. Micronutrients—Cu and Zn were extracted with 0.1 N HCl as described as in [8] and the concentration of nutrients determined with atomic adsorption spectrophotosmeter (Unicam Solaar 32: Cu Astm D1688; Zn Astm D1691).

2.2. Greenhouse Study

The greenhouse experiments were conducted to determine the optimum rate of Cu and Zn to maize dry matter yield and uptake, having observed in the laboratory experimental results that, these nutrients to be most deficient micronutrients. One kilogram of the soils was weighed into plastic pots of 2 L capacity placed on flat plastic receiver. The plastic pots were arranged in a complete randomized design (CRD) with four replications. The number of treatments for each experiment was seven while, the total number of plastic pots was 28 (7 × 4). Rates of 120 $kg{\cdot}N{\cdot}ha^{-1}$, 60 $kg{\cdot}P{\cdot}ha^{-1}$, 60 $kg{\cdot}K{\cdot}ha^{-1}$, and different levels of Cu and Zn (0, 2, 4, 6, 8, 10 and 12 $kg{\cdot}ha^{-1}$) as $CuSO_4$ and $ZnSO_4$ were used. Six seeds of Oba Supper II maize cultivar were sown per pot and thinned to four, two weeks following emergence. The reason for the small amount of soil and the number of maize seeds planted per pot was for research purpose, the soils need to be stressed up so that the levels of micronutrient applied will be able to establish a response curve. The soils in the pots were maintained at field capacity during the greenhouse study period by watering with deionized water. Plant shoots were harvested at 42 days after planting (6 WAP) by uprooting the entire maize plant (shoots and roots) from the soil. Maize plants were oven dried at 65˚C to constant weight. The dried plant samples were cut into small pieces and ground to pass through a 0.5 mm sieve for tissue analysis. The plant sample was digested with tri-acid using H_2SO_4-NHO_3-$HCLO_4$ [22] in Teflon crucible, heated on a hot plate. The content of Cu and Zn in the extracts were analyzed by atomic absorption spectrophotometer (Unicam model 939 AAS). Nutrient uptake ($mg{\cdot}plant^{-1}$) of maize plant was determined by multiplying dry matter yield ($g{\cdot}plant^{-1}$ MD) and concentrations of Cu and Zn ($mg{\cdot}kg^{-1}$) in plants [23].

2.3. Field Experiments

2.3.1. Location of the Study Site

The study site is at Calabar in Cross River State, located within Latitude 4˚N' and 7˚N', and Longitude 8˚E' and 8.30˚E' and in southern part of the tropical rain forest zone of Nigeria, to study the effects of various levels of Zn on grain yield, yield component and uptake by maize (*Zea mays* L.) at one of the sites where soil samples had been used for the greenhouse study (**Table 1**). The field was fairly flat and had been under continuous and intensive cultivation without the micronutrients fertilization. The soil is classified as Typic Paleudult according to USDA [24]. The parent materials (coastal plain sands) of the area consist of tertiary coastal sand deposits identified as quaternary [25]. These soils ranged from coarse to fine sandy texture [26]. According to FDALR [26], the parent materials greatly influences the type of soil found within the experimental site. The site experiences the south-westerly and northeasterly winds which is associated with the warm humid Maritime Tropical (MT) air mass respectively. As a result of the movement of these air masses winds, the region is characterized by two seasons-the wet season and the dry season. The wet season starts about March and last till October. This region has 2 - 3 months of dry seasons during which the total rainfall is less than 60 mm. The annual rainfall of the area was recorded as 3063 mm [27].

2.3.2. Experimental Design, Field Plan, and Treatments

Two separate experiments were conducted for Cu and Zn, using a randomized complete block design (RCBD),

Table 1. Mean annual and monthly precipitation (P), potential evapotranspiration (PET) and water balance for the location in Cross River State.

Station	Parameter	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	P	40	71	161	222	306	419	449	411	421	325	188	50	3063
Calabar	PET	80	85	91	85	79	64	53	51	58	69	76	83	887
	P-PET	−40	−14	70	137	227	355	396	360	363	256	112	−33	2176

Source: NIMETS [27].

with 7 treatments, replicated four times to give (7 × 4) 28 experimental plots. The dimension of each experimental plot was 6 m × 10 m (60 m^2), with interblock and interplot spacing of 2.5 and 2.0 m, respectively. A 2-m wide pathway was maintained around the entire experimental area. Maize seeds were sown at the spacing of 75 by 25 cm. Three seeds of Oba Supper ll maize cultivar were sown manually and 14 days after sowing, thinning to two seedlings was performed (recommended seed rate for this cultivar of maize in the rainforest zone for sole cropping at a plant population of 106,666 plant·ha^{-1}). Recommended doses of N, P and K at 120, 90 and 60 Kg·ha^{-1}, respectively were applied uniformly as Urea, SSP, MOP to all the plots three weeks after planting as a basal NPK fertilizers application [4]. Cu and Zn were applied at rates of (0.0, 2.0, 4.0, 6.0, 8.0, 10.0 and 12.0 Kg·ha^{-1}) as $CuSO_4$ and $ZnSO_4$, respectively, as side dressing. The reason for the selection of such high range rates of Cu and Zn was to observe the response curve for academic research purposes. Moreover, similar higher rates for Zn have also been reported in an earlier study conducted by Rashid and Fox [28]. Plants were sampled at 9 weeks after planting by taking three ear leaves per row from each of the net six out of eight rows, giving a total of 18 leaves per plot [10], when about 50% of maize plants had tasseled. The samples were oven dried at 65˚C to constant weight, cut into small pieces, and ground to pass through a 0.5 mm sieve for chemical analysis. Plants were grown till maturity, after which cobs were harvested at 120 days after which cobs were shelled; grain yields were measured and converted into tones·ha^{-1} at 12.5% moisture. Grains were ground using a Willey mill and digested using a tri-acid mixture of H_2SO_4:HNO_3:$HClO_4$ (1:2:1) as described before, and analyzed for Cu and Zn using atomic absorption spectrophotometer.

2.4. Statistical Analysis

The data collected were subjected to analysis of variance (ANOVA) procedure, using general linear model as in [29] and PASW Statistics 18 for Window 7.0. Significant means were separated using Fisher's Least Significant Different were appropriate at $P < 0.05$. Also correlation and regression analysis was carried out to establish the relationship between soil available Cu and Zn content, soil properties and yield parameters.

3. Results and Discussion

3.1. Laboratory Study

3.1.1. Soil Properties of the Study Site

Some physical and chemical properties of the experimental soils derived from coastal plain sand are shown in **Table 2**. The pH of the soil is 4.67 and is rate as low [11]. The optimum soil pH range for maize production is between 5 and 7 [3]. The pH of 4.67 could be considered suitable for crop production when other soil and plant factors are not limiting. Organic carbon in soil was found to be 1.06%. This value is rated to be low [30]. The low organic carbon could be explained by the fact that coastal plain sand derived soils normally have low organic carbon content [12] [25]. Nitrogen content in the soil was 0.19 g·kg^{-1}. Landon [30] categorized soil total N to range from 0.14 to 2.0 g·kg^{-1} as low, but soil total N ranged from 0.15% - 0.20% and was rated as moderately low [31]. Therefore, total N in the soil is rated as low. The Bray 1 (available) P content of the soil was 12.23 mg·kg^{-1}. Eextractable P (Bray 1 method) was categorized in soils as follows: high (>50); medium (15 - 50) and low (<15) [25] [30]. Therefore, an available P of 12.23 mg·kg^{-1} by the bray l method is very low, implying that the soil is deficient in P.

3.1.2. Status of Available Copper and Zinc in the Soil before the Experiment

The HCl-extractable Cu in the soil was 0.46 mg·kg^{-1}. Levels of 0.5 to 1.0 mg·kg^{-1} was being suggested to be the

Table 2. Some soil physical and chemical properties of experimental site.

S/NO	Soil parameter	Unit	Value	Rating
1	pH in water		4.79	Low
2	Organic Carbon	%	1.06	low
3	Available P (Bray 1)	$mg \cdot kg^{-1}$	12.23	Low
4	Total N	%	0.19	low
4	Cation exchange capacity	$cmol \cdot kg^{-1}$	16.89	Low
5	Exchangeable Ca	$cmol \cdot kg^{-1}$	3.60	Medium
6	Exchangeable Mg	$cmol \cdot kg^{-1}$	2.04	Medium
7	Exchangeable K	$cmol \cdot kg^{-1}$	1.34	High
8	Exchangeable Na	$cmol \cdot kg^{-1}$	0.15	Low
9	Exchangeable acidity	$cmol \cdot kg^{-1}$	1.30	-
10	HCl-extractable Cu	$mg \cdot kg^{-1}$	0.26	Low
11	HCl-extractable Zn	$mg \cdot kg^{-1}$	0.19	Low
	Particle size analysis			
12	Sand	%	75.60	
13	Silt	%	9.10	
14	Clay	%	15.30	
15	Textural class		Loamy sand	

critical levels for Cu, therefore, the concentration of 0.46mg $Cu \cdot kg^{-1}$ in the soil is rated as low, and this was contributed be due to low pH and organic matter of the soil [9]. Similarly, the HCl extractable Zn was found to be 0.19 $mg \cdot kg^{-1}$. Accordingly, [9] [11] [32], reported that the critical level of HCl-extractable Zn in the soil ranged from 0.2 to 1.0 $mg \cdot kg^{-1}$; therefore, an HCl-extractable Zn level of 0.19 $mg \cdot kg^{-1}$ in the soil is low or marginal, since it is below the soil critical levels reported. This finding is also in agreement with the report presented by [33] elsewhere in savanna soils of Northern Nigeria. The low available Cu and Zn in the soil as presented in **Table 2**, may be attributed to their low content in the parent material [34], low soil organic matter [35] and sorption or redox potential due to the prevailing pH of the soil [36] [37].

3.2. Greenhouse Experiments

3.2.1. Response of Maize to Cu and Zinc

Dry Matter Production of Maize Plants

An impressive effect of Cu treatment, on DM yields was determined. The DM yields of maize shoots differ significantly ($P < 0.05$) among the levels of Cu treatments, and this significantly increased DM yields from 6.82 to 17.69 $g \cdot plant^{-1}$ (**Table 3**). Higher dry matter yield was obtained at 10 $kg \cdot Cu \cdot ha^{-1}$ over control as given in **Table 3**. The significant ($P < 0.05$) increase in DM yield in the Cu treatments over the control suggests that Cu was one of the limiting nutrients in the soils (**Table 3**). However, the rate of 10 $kg \cdot Zn \cdot ha^{-1}$ will be required for optimizing maize yields in the soils, showing that this treatment improved better Cu nutrition for maize dry matter production in the soil, which in turn will improve maize grain yields.

Similarly, Zn levels significantly increased DM yields from 5.60 to 19.63 $g \cdot plant^{-1}$. The high increase in DM yields as a result of Zn application to the soil suggests that Zn was a limiting nutrient in the soil under review. The treatment that received 8 $kg \cdot Zn \cdot ha^{-1}$ gave significantly higher DM yield over control treatment. This indicates that, at this level, the soil Zn was further improved with better Zn nutrition leading to high DM production. Further addition of Zn to the soil after 8 $kg \cdot Zn \cdot ha^{-1}$ level, did not significantly in improve DM yield of plant shoots. This finding is in agreement with result reported in [10]. This which suggests that in this study, 8 $kg \cdot Zn \cdot ha^{-1}$ is the critical nutrient level that will optimize maize yields in Calabar acid sands soils.

Table 3. Effect of Cu and Zn levels on dry matter yield and their nutrient content in maize plant shoots.

Treatments	Dry matter yield ($g \cdot plant^{-1}$)	Nutrients content in maize plant shoots ($mg \cdot kg^{-1}$)
Cu levels ($kg \cdot ha^{-1}$)		
0	6.82	4.69
2	10.66	6.28
4	13.93	6.53
6	14.26	7.08
8	16.01	7.12
10	17.69	7.80
12	15.52	7.21
$LSD_{0.05}$	1.86	1.03
CV %	10.07	9.80
Zn levels ($kg \cdot ha^{-1}$)		
0	5.60	3.15
2	9.45	4.58
4	15.86	7.78
6	17.71	9.97
8	19.63	10.40
10	18.22	8.71
12	16.79	8.15
$LSD_{0.05}$	3.28	1.25
CV %	12.8	32.2

3.2.2. Concentration of Copper and Zinc Maize Shoots

The amounts of Cu concentrations in maize shoots are shown in **Table 3**. Copper concentration ranged from 4.63 to 9.47 $mg \cdot kg^{-1}$, these were far above the critical ranges of 0.2 to 1.0 $mg \cdot kg^{-1}$; 1.2 to 4.5 $mg \cdot kg^{-1}$ and a critical value of 5 $mg \cdot kg^{-1}$ reported by in [10] [38] [39], respectively. Moreover, Cu application increased Cu uptake significantly compared with the control, signifying that Cu was one of the limiting nutrients in this soil (**Table 3**). Surprisingly, lower levels of Cu also yielded higher concentration in maize shoots. It is noted in **Table 3** that, 10 $kg \cdot Cu \cdot ha^{-1}$ level applied, which gave the maximum dry matter production also gave significantly ($P < 0.05$) higher Cu content relative to lower levels of Cu. However, this rate of Cu is relatively high, suggesting that this soil has low Cu fixation [8].

Similarly, zinc concentrations in maize shoots varied between 3.15 and 10.40 $mg \cdot kg^{-1}$ (**Table 3**) and these were below the range of 10.8 to 18.9 $mg \cdot kg^{-1}$ obtained in [10] and critical levels of 25 to 60 $mg \cdot kg^{-1}$ established as in [40], however, these were above the critical level 7 $mg \cdot kg^{-1}$ for maize at 42 days of age [39]. Table 3 above showed that 8 $kg \cdot Zn \cdot ha^{-1}$ level generated significantly ($P < 0.05$) higher Zn content in maize shoot over control. Interestingly, at this levels the application of Zn significantly ($P < 0.05$) gave higher DM yields relative to lower treatments and those above it, suggesting that, there is a dilution of Zn in the maize plant by the rapid maize growth and yield, as found in dry matter production, Zn concentration and Zn uptake in plant shoots (**Table 3** and **Figure 2**), respectively.

3.2.3. Estimation of Optimum Copper and Zinc Levels for Maize Production in Calabar Acid Sands Soil

1) Uptake of Copper and Zinc

Copper application increased Cu uptake in maize shoots significantly ($P < 0.05$), compared with the control, indicating that Cu must have been one of the limiting nutrients in the soil and it was also in this treatment level where significantly, higher Dm yield was obtained. The treatment that received 10 kg·Cu·ha^{-1} gave significant higher uptake than treatments with low Cu levels as indicated in **Figure 1**, suggesting that this level improved Cu supply further, thereby leading to better Cu nutrition. **Figure 1** also indicated that Calabar acid sands soils contain a low to marginal level of Cu that is why there was this impressive response of maize to Cu application. However, further addition of Cu in the soil above the 10 kg·Cu·ha^{-1}, did not yield any increase in Cu uptake significantly, probably due to a dilution affect as a result of the increased in DM yield in maize shoot. Accordingly, the polynomial regression analysis ($Y = 0.3238 + 0.1791X - 0.009X^2$; $R^2 = 0.9496$) computed for Cu uptake as shown in **Figure 1**, suggest that the optimum levels for Cu uptake in maize shoots as influenced by Cu levels to be 10.06 kg·Cu·ha^{-1}.

Similarly, there was a significant effect of different levels of Zn application on Zn uptake in maize plants (**Figure 2**). The incremental addition of $ZnSO_4$ to the soil significantly ($P < 0.05$) improved Zn uptake in maize, leading to the maximum increase in Zn uptake of maize shoots and this was determined in Zn applied at 8 kg·Zn·ha^{-1} over the control treatment (**Figure 2**). This result may be due to the increase in either DM yield or Zn concentration which accumulated Zn content in the various plant parts. This finding is in agreement with those reported as in [41]-[43]. Elsewhere as in [10], higher rates than the rate used in this study were applied, and obtained a similar result. It is however, noted in **Figure 2** that, Zn uptake was significantly ($P < 0.05$) increased according to levels of Zn fertilizer applied, while at 12 kg·Zn·ha^{-1}, Zn uptake by maize descended. Furthermore, the polynomial regression analysis computed for Zn uptake ($Y = 0.0048 + 0.4377X - 0.0266X^2$; $R^2 = 0.931$) indicated that the optimum level for Zn uptake in maize shoots as influenced by levels of Zn is also determined to be 8 kg·Zn·ha^{-1} in Calabar acid sands soils. The result of this study indicates that the soils of

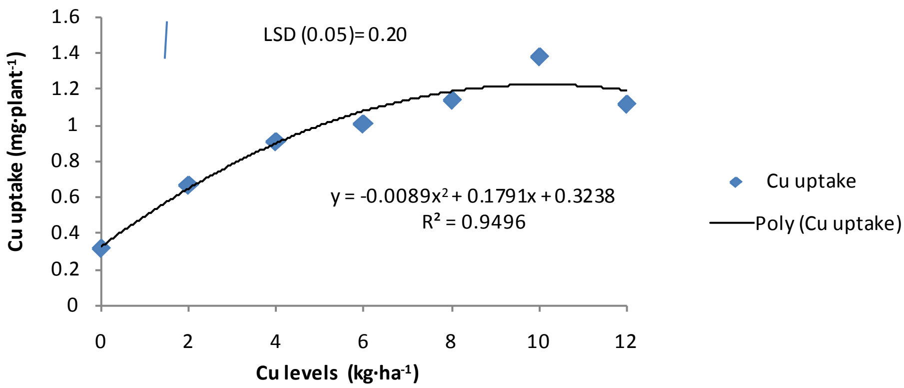

Figure 1. Optimum levels of Cu uptake on maize plant in greenhouse study. Vertical bar represents LSD at 0.05.

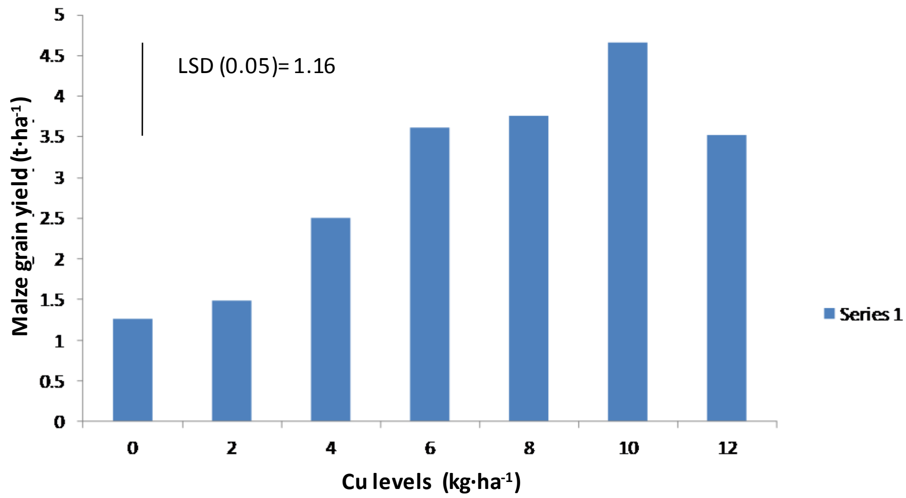

Figure 2. Effect of Cu levels on maize grain yields. Vertical bar represents LSD (0.05).

Calabar, Nigeria exhibited a highly variable capacity to accumulate Zn due to Zn supplement, less fixation and greater transport of the nutrient to plant roots [4] [31].

3.3. Field Experiments

Maize Grain Yields

Result on **Figure 3** showed that maximum grain yield was obtained with the application of 10 kg·Cu·ha^{-1} and minimum was recorded in the control plot. It is also evident from **Figure 3** that all the copper treated plots significantly ($P < 0.05$) increased the grain yield over the control, as there was a consistent increase in maize grain yield up to 10 kg·Cu·ha^{-1}, perhaps due to toxic level of applied Cu. This suggest that, the application of Cu significantly ($P < 0.05$) influenced the increased in maize grain yield. Similar results were reported as in [10]. The result is in accord with the earlier report that plants grown in acid sands respond to Cu application even if the soil is not deficient in available Cu [44]. However, the low grain yield obtained in control plots suggest that the soils was actually deficient in Cu available to the plants, being that this level is critical for growing maize. Generally, the grain yield enhancement at 10 kg·Cu·ha^{-1} suggest that, this is the level required for optimum maize production in the soils under review.

Similarly, the application of Zn significantly ($P < 0.05$) increased maize grain yields (**Figure 4**). Maize grain yield was significantly increased by the application of 8 kg·Zn·ha^{-1}, however, further addition did not significantly result in corresponding yield increase (**Figure 4**). This may be due to Zn levels in the soils. This rate was lower than the level obtained as reported in [45] who reported a grain yield increase of 116.25 as a result of 10 kg·Zn·ha^{-1} application over control, elsewhere in Ghana. However, the level obtained in this study was higher than the optimum level obtained in [43] who reported a grain yield increased in maize from 1977-1999 ranged

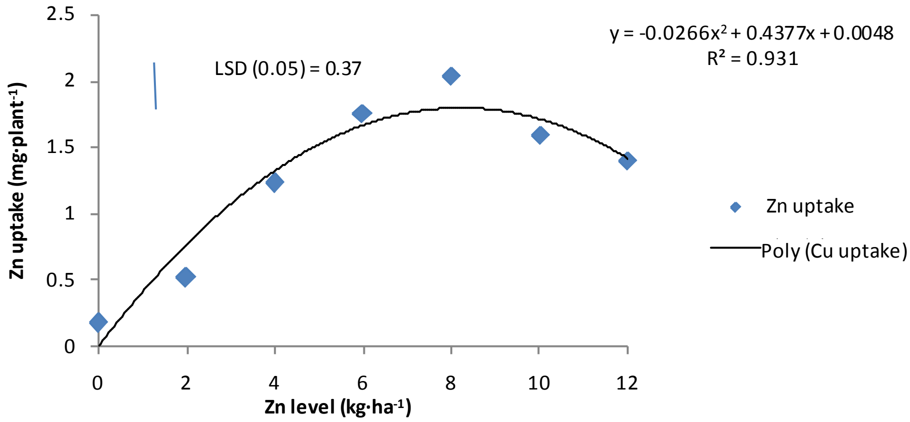

Figure 3. Optimum levels of Zn uptake on maize plants in greenhouse study. Vertical bar represent LSD at 0.05.

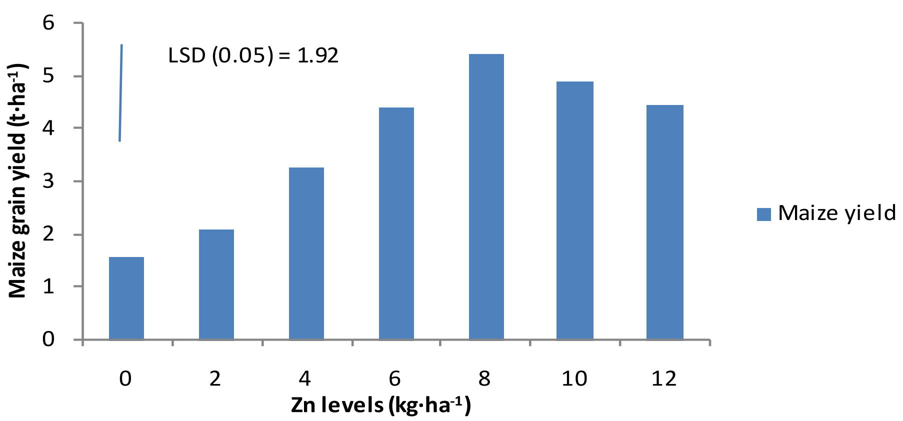

Figure 4. Effect of Zn levels on maize grain yield.

between 84% to 108% with the highest percentage increased at 10 kg·Zn·ha^{-1}. Moreover, considering the low levels of Zn uptake by maize plant and the higher grain yield obtained when Zn was applied at 8 kg·Zn·ha^{-1}, it is an impression that $ZnSO_4$ application at this level is appropriate for maize production in these soils.

However, the application of Cu and Zn fertilizers to the maize crop in different experiments, not only enhances its production in the soils, but also increases tissue content and this can cure the micronutrients deficiency problem in human nutrition [46]. Moreover, the response of maize as influenced by levels of Cu and Zn fertilizers respectively in separate field experiments are in agreement with those obtained from greenhouse experiments.

4. Conclusion

The study clearly demonstrated that coastal plain sand derived soil has severe Cu and Zn deficiency. The potential impacts of Cu and Zn fertilizers to improve on maize grain yields were clearly demonstrated, appreciably in the soil. A greenhouse experiment estimated approximately a level of 10 kg·Cu·ha^{-1} and 8 kg·Zn·ha^{-1} to be optimum levels for dry matter production, contents of Cu and Zn and its uptake in maize shoots, respectively in the study area. Besides, the application of Cu and Zn fertilizers in the field yielded maximum grain yield at the rate of 10 kg·Cu·ha^{-1} and 8 kg·Zn·ha^{-1}, respectively. Accordingly, the rates of 10 kg·Cu·ha^{-1} and 8 kg·Zn·ha^{-1} are recommended in Calabar soil to ensure that the yield potentials of maize are achieved. Furthermore, research should be undertaken on the chemistry and adsorption of Cu and Zn to identify the adsorption or retention capacity of the soil. Further research should be conducted to evaluate sorption and/or the use of organic Cu and Zn fertilizers especially Cu/Zn-EDTA, Cu/Zn-Lignosulphate and Cu/Zn-Suc. Also the potentials of these nutrient minerals with other crops like roots and tubers, and vegetable crops in other areas of coastal plain sand derived soil should be examined.

References

[1] IITA (2010) Annual Report on Maize Production. International Institute of Tropical Agriculture, Ibadan.

[2] FAO (2010) FAO Production Year Book. Food and Agricultural Organization, Rome.

[3] Enwezor, W.O., Ohiri, O.C., Opuwaribu, E.E. and Udo, E.J. (1990) A Review of Fertilizer Use on Crops in Southeastern Zones of Nigeria (in Five Vols.) (FFDD Eds). Boboma Publ., Ibadan, 47-70.

[4] Chude, V.O., Malgwi, W.B., Amapu, I.Y. and Ano, A.O. (2004) Manual on Soil Fertility Assessment. Federal Fertilizer Department/National Special Food Programme for Security, Abuja, 89.

[5] Ogban, P.I., Akwue, I.P. and Mauako, O. (1999) Properties and Management of Catenary Soils on Coastal Plain Sands in Southeastern Nigeria. In: Babalolu, O., Omoti, U. and Isenmila, A.E., Eds., *Management of the Soil Resources of Nigeria for Sustainable Agricultural Production in the* 21*st Century*. *Proceedings of the* 25*th Annual Conference of the Soil Science Society of Nigeria*, Benin, 45-52.

[6] Onwuka, I.M. (2008) Amelioration of Soil Acidity Using Local Liming Materials and Their Effects on Maize Performance in an Ultisols of Southeastern Nigeria. Ph.D. Thesis, Department of Soil Science and Meteorology, Michael Okpara University of Agriculture, Umudike, 123.

[7] Sillanpaa, M. (1982) Micronutrients and the Nutrient Status of Soils: A Global Study. FAO Soil Bulletin No. 48, FAO/ Finnish International Development agency, Rome.

[8] Osiname, O.A., Schulte, E.E. and Core, R.B. (1973) Soil Tests for Available Copper and Zinc in Soils of Western Nigeria. *Journal of the Science of Food and Agriculture*, **24**, 1341-1349. http://dx.doi.org/10.1002/jsfa.2740241105

[9] Kparmwang, T., Chude, V.O., Raji, B.A. and Odunze, A.C. (2000) Extractable Micronutrients in Some Soils Developed on Sandstone and Shale in Benue Valley, Nigeria. *Nigerian Journal of Soil Science Research*, **1**, 42-48.

[10] Lisuma, J.B., Semoka, J.M.R. and Semu, E. (2006) Maize Yield Response and Nutrient Uptake after Micronutrient Application on a Volcanic Soil. *Agronomy Journal*, **98**, 402-406.

[11] Aduayi, E.A., Chude, V.O., Adebusuyi, B.A. and Olayiwola, S.O. (2002) Fertilizer use and Management Practices for Crops in Nigeria. Federal Fertilizer Distribution Department. Federal Ministry of Agriculture and Rural Development, Abuja, 126.

[12] Enwezor, W.O., Udo, E.J. and Sobulo, R.A. (1981) Fertility Status and Productivity of Acid Sands. In: *Acid Sands of Southeastern Nigeria*, SSSN Special Publication Lagos, Nigeria, Monograph No. 1: 56-73.

[13] Iwuafor, E.N., Chude, V.O. and Amapu, I. (1991) Response of Maize (*Zea mays* L.) to Various Rates of Zinc Fertilizer in the Semi-Arid Zone of Nigeria. *SAFGRA Network*'*s Joint Workshop*, Niamey, 8-14 March 1991.

[14] Yusuf, A.A., Abdu, N., Chude, V.O., Yusuf, H.A. and Pam, S.G. (2005) Response of Maize (*Zea mays L.*) to Zinc Fertilization in Relation to Mehlich l Extractable Zinc in Northern Nigeria. *Nigeria Journal of Soil Research*, **6**, 32-41.

[15] Chude, V.O., Iwuafor, E.N.O., Amapu, I.Y. and Pam, S.G. and Yusuf, A.A. (2002) Response of Maize to Zn Fertilization in Relation to Mehlich III Extractable Zinc. (in Press)

[16] Ojanuga, A.G. (2006) Agroecological Zones of Nigeria Manual. In: Berding, F. and Chude, V.O., Eds., *National Special Programme for Food Security* (*NSPFS*) *and FAO*, 124.

[17] Thomas, G.W. (1996) Soil pH and Soil Acidity. In: Sparks, D.L., Ed., *Methods of Soil Analysis Part* 3: *Chemical Methods*, SSSA Book Series 5, Soil Science Society of America, Madison, Wisconsin, 475-490.

[18] Nelson, D.W. and Sommers, L.E. (1996) Total Carbon, Organic Carbon and Organic Matter. In: Sparks, D.L., Ed., *Methods of Soil Analysis Part* 3: *Chemical Methods*, SSSA Book Series 5, Madison, Wisconsin, Soil Science Society of America, 961-1010.

[19] Kuo, S. (1996) Phosphorus. In: Sparks, D.L., Ed., *Methods of Soil Analysis Part* 3: *Chemical Methods*, SSSA Book Series 5, Soil Science Society of America, Madison, Wisconsin, 869-920.

[20] Bremner, J.M. (1996) Nitrogen Total. In: Sparks, D.L., Ed., *Methods of Soil Analysis Part* 3: *Chemical Methods*, SSSA Book Series 5, Soil Science Society of America, Madison, Wisconsin, 1085-1122.

[21] Sumner, M.E. and Miller, W.P. (1996) Cation Exchange Capacity and Exchange Coefficients. In: Sparks, D.L., Ed., *Methods of Soil Analysis Part* 3: *Chemical Methods*, SSSA Book Series 5, Soil Science Society of America, Madison, Wisconsin, 1201-1230.

[22] Shuman, L.M. (1985) Fractionation Method for Soil Micronutrients. *Soil Science*, **140**, 11-22. http://dx.doi.org/10.1097/00010694-198507000-00003

[23] Whitney, D.A. (1988) Micronutrient Soil Test Zinc, Iron, Manganese and Copper. In: Dahuke, W.C., Ed., *Recommended Chemical Soil Test Procedures for the North Central Region*, North Dakota Agric. Exp. Stn. Bull. 499 Review, 20-22.

[24] USDA (2006) Keys to Soil Taxonomy. 10th Edition, United States Department of Agriculture, NRCS Soil Conservation Service, Washington DC.

[25] Ibanga, I.J. and Udo, E.J. (1996) Soil Survey and Fertility Baseline Data collection of Akwa Ikot Effangha Farm, Akpabuyo LGA, Cross River State Nigeria. National Agricultural Land Development Authority, Abuja.

[26] FDALR (1995) Federal Department of Agriculture and Land Resources. The Reconnaissance Soil Survey of Cross River State, Nigeria. FDALR, Abuja, 43p.

[27] NIMETS (2009) Nigeria Meteorological Services, Calabar Station, Margerate Ekpo International Airport Calabar, Nigeria.

[28] Rashid, A. and Fox, R.C. (1992) Evaluating Internal Zn Requirements of Grain Crop, In: *Methods of Soil Analysis. Part* 2: *Chemical and Microbiological Properties*, Agronomia, Soil Science Society of America, Madison, WI. 9: 570-571.

[29] GenStat (2003) GenStat for Windows. Release 7.2. 7th Edition, VSN International Ltd, Oxford.

[30] Landon, J.R. (1991) Booker Tropical Soil Manual. A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and sub Tropics. Longman Scientific & Technical Publ., Harlon.

[31] Enwezor, W.O., Udo, E.J., Usoro, N.J., Ayotade, J.A., Chude, V.O. and Udegbe, C.C. (1989) Fertilizer Use and Management Practices for Crops in Nigeria. Series 2. Federal Ministry of Agriculture, Water Resources and Rural Development, 52-56.

[32] Tandon, H.L.S. (1995) Micronutrients in Soils, Crops and Fertilizer: A Source Book-Cum-Directory. Fertilizer Development and Consultation Organ, New Delhi.

[33] Abdu, N., Yusuf, A.A., Abdulkadir, A., Arunah, U.L., Chude, V.O. and Pam, S.G. (2007) Zinc Soil Calibration Based on 0.1 N HCl Extractable Zinc and Cation Exhangeable Capacity from Upland Soils of Northern Nigeria. *Journal of Agronomy*, **6**, 179-182. http://dx.doi.org/10.3923/ja.2007.179.182

[34] Alloway, B.J. (2004) Zinc in Soils and Crop Nutrition. International fertilizer Industry Association and International Zinc Association, Brussels, Belgium and Paris, 135.

[35] Ano, A.O. and Agwu, J.A. (2005) Effect of Animal Manures on Selected Soil Chemical Properties (1); Exhangeable Acidity. Exchangeable Bases and Organic Carbon. *Nigeria Journal of Soil Science*, **15**, 14-19.

[36] Eshiet, E.T. (1992) Physico-Chemical, Morphological and Mineralogical Characteristics of Selected Humid Region Profiles in Southeastern Nigeria. In: Kimble, J.M., Ed., *Proceedings of the Eighth International Soil Correlation Meeting* (*VIII ISCOM*): *Characterization, Classification and Utilization of Wet Soils*, USDA, Soil Conservation Service, National Soil Survey Center, Lincoln, NE, 100-105.

[37] Akamigbo F.O.R. and Asadu, C.L.A. (1983) Influence of Parent Materials on the Soils of Southeastern Nigeria. *East African Agricultural Journal*, **48**, 81-91.

[38] Udo, E.J. and Fagbami, A.A. (1979) The Profile Distribution of Total and Extractable Zn in Selected Nigerian Soils. *Communications in Soil Science and Plant Analysis*, **10**, 1141-1161. http://dx.doi.org/10.1080/00103627909366968

[39] Jones, J.B. and Eck, H.V. (1973) Plant Analysis as an Aid in Fertilizing Corn and Grain Sorghum. In: Watsh, L.M. and Beaton, J.B., Eds., *Soil Testing and Plant Analysis*, SSSA, Madison, WF, 349-364.

[40] Tisdale, L.S., Werner, N.L., Beaton, S.D. and Havlin, J.L. (2003) Soil Fertility and Fertilizers. 6th Edition, Prentice-Hall, Upper Saddle River, NJ, 634p.

[41] Rhem, G.W., Wiese, R.A. and Herget, G.W. (1980) Response of Corn to Zn Sources and Rate of Zn Band-Applied with Either Orthophosphate or Polyphosphate. *Soil Science*, **129**, 36-44. http://dx.doi.org/10.1097/00010694-198001000-00007

[42] Kanwal, S., Rahmatullah, A.M. Ranjha and R. Ahmad (2010) Zinc Partitioning in Maize Grain after Soil Fertilization with Zinc Sulphate. *International Journal of Agriculture and Biology*, **12**, 299-302.

[43] Maftoun, M. and Karimian, N. (1989) Relative Efficiency of Two Zn Sources for Maize (*Zea mays* L.) in Two Calcareous Soils from an Arid Area of Iran. *Agronomie*, **9**, 771-775. http://dx.doi.org/10.1051/agro:19890804

[44] Abunyewa, A.A. and Mercer-Quarshie, H. (2004) Response of Maize to Zinc Application in the Semi Arid Zone of West Africa. *Asian Journal of Plant Sciences*, **3**, 1-5. http://dx.doi.org/10.3923/ajps.2004.1.5

[45] Ibanga, I.J., Lekwa, J., Eko, U.C., Udo-Isong, M.N., Ugwu, T.T. and Ahumile, C. (1989) Soil and Land Use Survey of Cross River State. Main Bulk trade Investment, Calabar.

[46] Frey, E., Frolich, W., Hauffe, H.K. and Rudat, H. (1999) The Effect of Mg and Zn Application to Maize in an Alfisol in Northern Ghana. *The* 12*th National Maize and Legumes Workshop*, Technical Institution, Kumasi, 24-26.


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