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Effect of Cu AND Zn On Maize (Zea Mays L.) Yield and Nutrient Uptake in Coastal Plain Sand Derived Soils of Southeastern Nigeria

Eteng[1], E. U., Asawalam[1], D. O. and Ano[2], A. O.
[1]Department of Soil Science and Meteorology, Michael Okpara University of Agriculture, Umudike. [3] National Root Crop Research Institude, Umudike. Corresponding author's e-mail: eteng_em@hahoo.com

Abstract
Micronutrients, which are often found to be lacking in coastal plain sand derived soils, can lead to higher crop yields in this area. The use of Cu and Zn as fertilizers could be a variable option to fulfill the demand for these elements and also to increase its contents in maize grains. In this study, 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 would increase maize grain yields 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 yield was 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. A recommended N, P, and K at rates of 120, 60, 30 kg ha^{-1}, respectively, were also used as basal application. The status of available Cu and Zn by 0.1 HCl were found to be low in the soil. The application of Cu and Zn into the soils significantly ($P<0.05$) increased both maize DM and grain yields. Maximum grain yields and uptake in maize were established at 10 kg Cu ha^{-1} and 8 kg Zn ha^{-1}, respectively. The estimated optimum rates for Cu and Zn under greenhouse environments 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 35.9 mg kg^{-1}, while for Zn it was 32.1 mg kg^{-1}. The current study showed that though the soils has a severe Cu and Zn deficiency, which could be due to their strong sorption capacity, and nutrients mining, due to intensive cropping, maize production can still be increased considerably in this soil and other similar soils in the same agroecological 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.

Introduction

It is well known that many factors such as pH, soil organic matter and fertilizer application affects the concentration of mineral nutrients of the soil and the available nutrient concentration (FFDD, 2002). However, mineral fertilization is one of the most important yield factors. Acid soils of southeastern Nigeria, low in fertility frequently present nutrient deficiencies in both annual and perennial crops (FFDD, 2002). Moreover, apart from NPK, other nutrients elements suspected to be limiting in southeastern Nigeria soils include the micronutrients such as Zn, Cu, Fe and Mn (Chude et al., 2004). Micronutrient-deficient soils generally do not support optimum crop yields because plant growth becomes retarded by the deficiency, leading to low yields.

Of the micronutrients, Cu and Zn deficiency is thought to be the widespread (Cakmak et at. 1999). Zinc (Zn) deficiency is a common micronutrient deficiency in many parts of the world and also in soils of southeastern Nigeria. These soils are rich in total content of Zn although the levels of plant available Zn is extremely low (Enwezor *et al.*, 1990). Thus, the existence of low Zn concentration in soils resulted in depression in plant growth and yield.

The approaches that have been used to replenish 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. Soluble sulphate of copper and zinc are some other sources of micronutrients that can be used 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. Currently, it is possible for most small-income farmers who engaged in cultivating vegetables and arable crops like cassava and maize, to use these soluble micronutrients which are less expensive and available. Field experiments conducted in coastal plain sand derived soil, 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, Lisuma et al (2006) reported a yield range from 1.76 to 5.84 t ha^{-1} from treatment rates of 2.5 kg Cu ha^{-1} and 5 kg Zn ha^{-1}, however, the soils in southeastern Nigeria environment could support yields in excess of 5 t ha^{-1} once the limiting nutrients are corrected (FFDD, 2002). 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 (Enwezor et al., 1981). Such conditions are favourable for high yields of maize once any limiting nutrients are corrected (FFDD, 2002). The main objectives of this study were: (i) to evaluate the status of Cu and Zn in Akpabuyo soil and, (ii) to assess whether the addition of these micronutrients would increase maize grain yields and yield component in this soil.

Materials and Methods

Soil samples were collected from a site that had not been treated with micronutrient fertilizers for the past 2 years for laboratory and greenhouse experiments. The soil has been classified as a Typic Paleudult according to USDA system of classification (USDA, 2006). The site was selected as representative of coastal plain sand derived soil, in Akpabuyo a suburb of Calabar municipality in southeastern Nigeria, which has a high potential for dual seasons maize production. The soils are also suitable for production of upland/swamp rice, okro, yam, cassava, citrus, oil palms and recently some pineapple genotypes, have been introduced into the area because of their high market demands for local consumption and export.

Laboratory Study

Laboratory study was conducted to determine some of the physical and chemical properties of Akpabuyo coastal plain sands derived soil and the status of total and available Cu and Zn in the study area having been informed that these nutrients to be limiting micronutrients (Enwezor et al., 1990). 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), organic carbon was determined by wet oxidation (Nelson and Sommer, 1982), available P was determined by Bray 1 method (Bray and Kurtz, 1945), and total N was determined by Kjeldahl procedure of Mkenzie (2003). Effective cation exchange capacity and exchangeable cations were determined by the method described by Juo (1979). Micronutrients – Cu and Zn were extracted with 0.1 N HCl as described by Osiname et al (1973) and the concentration of nutrients determined with atomic adsorption spectrophotosmeter (Unicam Solaar 32: Cu Astm D1688; Zn Astm D1691).

Greenhouse Study

The greenhouse experiments were conducted to determine the optimum rate of Cu and Zn to maximize maize yields, having observed in the laboratory experimental results that, these nutrients to be most deficient micronutrients. The plastic pots were arranged in a complete randomized design with four replications. The total number of treatments for each experiment was seven while, the total number of plastic pots was 28. Rates of 120 kg N ha^{-1}, 60 kg P ha^{-1}, 60 kg K ha^{-1}, and different levels of Cu and Zn (0, 2, 4, 6, 8, 10 and 12 kg ha^{-1}) as $CuSO_4$ and $ZnSO_4$ were used. Four seeds of Oba Supper ll maize cultivar were sown per pot and thinned to three two weeks following emergence. 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 by uprooting the entire maize plant from the soil. Maize plants were oven dried at 70^{o}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.

Field experiments

Location of the study site

Akpabuyo a suburb of Calabar in southeastern, Nigeria is located within Latitude 4^{o} N' and 7^{o} N', and longitude 8^{o} E' and 8.30^{o} E' and South of the rain forest zone of Nigeria (FDALR, 1995). The parent materials of the area consist of tertiary coastal sand deposits identified as quaternary. These soils ranged from coarse to fine sandy texture (FDALR, 1995). The Cross, Great Kwa and Calabar rivers dissect the loose sand deposits creating repeatedly undulating topography with abrupt valleys. According to FDALR (1995), 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 November. This region has 2-3 months of dry seasons during which the total rainfall is less than 60mm monthly and annual rainfall. The annual rainfall of the area was recorded as 3068mm.

Experimental design, Field plan, and Treatments

Two separate experiments for Cu and Zn were conducted using a randomized complete block design, with 7 treatments, replicated four times. The dimensions of each plot were 5 x 10 m, 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 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. Cu and Zn was 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 (1992). Plants were sampled at 9 weeks after planting by taking three ear leaves per row from each of the net five out of eight rows, giving a total of 15 leaves per plot (Lisuma et al., 2006), when about 50% of maize plants had tasseled. The samples were oven dried at 70^0 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 Wily mill and digested using a diacid mixture of HNO_3: $HClO_4$ (2:1) and analyzed for Cu and Zn using atomic absorption spectrophotometer (Chapman and Pratt, 1961). Analysis of variance was used to evaluate the effects of treatments on dry matter (DM) yield, contents of Cu and Zn in plant samples, and maize grain yield. Least significant difference test was used for the separation of means.

Results and Discussion

Laboratory Study

Soil Properties of the Experimental Site

Some of the physical and chemical properties of Akpabuyo soils derived from coastal plain sand are shown in Table 1. The pH of the soil is 4.67 and is rate as low (FFDD, 2002). The optimum soil pH range for maize production is between 5 and 7 (Purseglove, 1988; Enwezor et al., 1990). The pH of 4.67 could be considered suitable for crop production when other soil and plant factors are not limiting. Organic C in Akpabuyo soil was found to be 1.06%. This value is rated to be low (Landon, 1991). The low organic C could be explained by the fact that coastal plain sand derived soils normally have a low organic C content (Enwezor et al., 1981; Ibanga and Udo, 1996). Nitrogen content in the soil was 0.19 g kg^{-1}. Landon (1991) categorized soil total N to range from 0.14 to 2.0 g kg^{-1} as low. Therefore, total N in Akpabuyo coastal plain sand derived soil is rated as low. The Bray 1 (available) P content of the soil was 12.23 mg kg^{-1}. Landon (1991) and Ibanga and Udo (1996) categorized extractable P (Bray 1 method) in soils as follows: high (>50); medium (15-50) and low (<15). Therefore, an available P of 12.23 mg kg^{-1} by the bray 1 method is very low, implying that the soil is deficient in P.

The HCl-extractable Cu in the soil was 0.46 mg kg^{-1}. Kparnwang et al. (2000) suggested levels of 0.5 to 1.0 mg kg^{-1} to be the critical levels for Cu, therefore, the concentration of 0.46mg Cu kg^{-1} for Akpabuyo soil is rated as low. The HCl extractable Zn was found to be 0.19 mg kg^{-1}. According to Tandon (1995); Kparnwang et al. (2000) and FFDD (2002), the critical level of HCl-extractable Zn in the soil ranged from 0.2 to 1.0 mg kg^{-1}; therefore, an HCl-extractable Zn level of 0.19 mg kg^{-1} in the soil is low since it is below the soil critical level reported elsewhere.

Greenhouse Experiments

Response of maize to Copper and zinc

An impressive effect of Cu treatment, on DM yields was observed, which significantly increased DM yields from 6.82 to 17.69 g plant^{-1} (Table 2). The increased in the DM yields reveals Cu as a limiting micronutrient in the soils of Akpabuyo coastal plain sand, and therefore, the significant ($P<0.05$) increase in yields following its fertilization. Similarly, Zn levels significantly increased DM yields from 5.60 to 19.63 g plant^{-1}. The high increase in DM yields as a result of Zn application suggests that Zn was a limiting nutrient in the soil under review. The higher ($P<0.05$) Dm yields when Zn was treated at the rate of 6 kg ha^{-1} relative to higher rates implies that higher DM yields beyond the 19.63 g plant^{-1} may be obtained in the area if, Zn level is increased to at least 8 kg ha^{-1} that will optimized maize yields. Lisuma et al (2006) applied higher rate than the rate used in this study.

Concentration and Uptake of Copper and Zinc in Maize Shoots

The concentrations of Cu and Zn, and their uptake by maize shoots are shown in Table 2 and 3 respectively. Copper concentration ranged from 5.63 to 9.47 mg kg^{-1}, these were far above the critical ranges of 0.2 to 1.0 mg kg^{-1}; 1.2 to 4.5 mg kg^{-1} and a critical value of 5 mg kg^{-1}reported by Udo et al (1979), Lisuma et al (2006) and Jones Eck (1973) respectively. Moreover, Cu application increased Cu uptake significantly compared with the control, signifying that Cu was one of the limiting nutrients in this soil. It is observed that the rate that gave significantly higher DM yields also gave a significant higher Cu uptake. Similarly, zinc concentrations in maize shoots varied between 3.15 and 10.40 mg kg^{-1} and these were below the range of 10.8 to 18.9 mg kg^{-1} obtained by Lisuma et al (2006) and critical levels of 25 to 60 mg kg^{-1} established by Tisdale et al (1993). Similarly, soil analysis data for Zn showed that Akpabuyo coastal plain sand derived soil had low level of Zn. Addition of Zn from 8 to 12 kg ha^{-1} in the soil did not significantly ($P<0.05$) increase Zn concentrations and uptake either in maize shoots, probably due to a dilution effect as a result of the high increase in DM starting from when 6 kg ha^{-1} of Zn was applied. The higher and significant Zn uptake for the treatments with 8 and 10 kg ha^{-1} could not be related to the large decrease in DM yield at these rates of application.

Estimation of optimum copper and zinc levels for maize production in Akpabuyo soil.
Response of maize dry matter yield to different levels of copper and Zn
The higher increase in Dm yields in the Cu treatments over the control suggests that Cu was a limiting micronutrient (Table 2). The DM yields of maize shoots differ significantly ($P<0.05$) among the levels of Cu treatments. The treatment that received 10 kg Cu ha^{-1} gave significantly higher DM yield than treatments with 6 kg Cu ha^{-1} and lower rates. However, the rate of 14 kg Zn ha^{-1} will be required for optimizing maize yields in Akpabuyo soils, showing that this treatment improved better Cu nutrition for maize production in the soil. Levels of zinc application to soil significant ($P<0.05$) increased DM yield of maize shoots over the control suggesting that Zn was also limiting in the soil (Table 3). The treatment that received 8 kg Zn ha^{-1} gave significantly higher Dm yield over other treatments. This indicates that at this level, DM yield of maize was further improved thereby leading to Zn supply with better Zn nutrition.

Concentration and uptake of copper and zinc in Maize shoots
Most of the Cu concentrations in maize shoots were above the critical level 7 mg kg^{-1} (Table 2), which is the lower value of sufficiency range for maize at 42 days of age (Jones and Eck, 1973; Lisuma et al., 2006). The rate of 10 kg Cu ha^{-1} will be required for optimizing maize yields in Akpabuyo soils. It was noted here that this level gave significantly ($p<0.05$) higher DM yields relative to lower levels of Cu. However, this rate of Cu is relatively high, suggesting that this soil has high Cu fixation. Results in Table 3 shows that greater portions of Zn concentrations in maize shoots were above the critical level 7 mg kg^{-1} for maize at 42 days of age (Jones and Eck, 1973). Though 8 kg Zn ha^{-1} level generated significantly ($P>0.05$) higher Zn content in maize shoot, Zn level of 10 kg Zn ha^{-1} was needed for optimum maize yields in the soils. Moreover, this rate 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 Cu in the maize plant by the rapid maize growth.

Field Experiment
Maize grain yields
Maize grain yields treated with Cu varied from 1.26 to 4.66 t ha^{-1} (Table 2). The gain yield of 4.66 t ha^{-1} was obtained from Cu treatment at 10 kg ha^{-1} and this was significantly ($P<0.05$) higher than that from the control and the rest of the treatments. The result obtained in this study indicates that Cu significantly influenced maize grain yields. Similarly, the application of Zn significantly ($P<0.05$) increased maize grain yields (Table 3). The maize grain yield however, ranged between 1.55 and 5.23 t ha^{-1} among the Zn treatments. The highest, and significant ($P<0.05$) maize grain yield across all the treatments was obtained by Zn treated with 8 kg ha^{-1}. 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 beings (Kanwal et al., 2010). Moreover, the grain yield results obtained from the application of Cu and Zn fertilizers respectively in separate field experiments are in agreement with those obtained from greenhouse experiments. Nevertheless, higher maize yields can be harvested in soils of Akpabuyo beyond the 4.66 t ha^{-1} and 5.23 t ha^{-1} if the application Cu and Zn respectively and other agronomic conditions are optimized. However, a graphical analyses of Cate and Nelson model indicates that Cu level of at least 16 kg ha^{-1} is suggested, and on the basis of second cropping, as the level that can optimize maize yields under the current used nutrient fertilization rates.

Concentration of copper and zinc
The concentration of Cu ranged from 1.74 to 3.59 mg kg^{-1} (Table 2) and were below the critical values of 5 mg kg^{-1} reported by Jones and Eck (1973), but these were above the critical level of 1 mg kg^{-1} rated as high, given by Udo et al. (1979) and a range of 0.45-1.44 mg kg^{-1} reported by Lisuma et al. (2006). The maize plants treated with Cu showed lower concentrations of Cu while, the grain yield was significantly higher, suggesting that the Cu requirement for grain formation is higher than that for maize shoots growth. In the same vein, the concentration of Zn varied between 16.31 to 32.14 mg kg^{-1} (Table 3). On the average, these were above the critical ranges of 0.8-2.0 mg kg^{-1} reported by Udo et al. (1979). On the contrary, maize plants treated with Zn showed higher concentrations while the grain yield was significantly lower, suggesting that the Zn requirement for grain formation is lesser than that for maize shoots growth.

Conclusions
The study clearly demonstrated that coastal plain sand derived soil at Akpabuyo has severe Cu and Zn

deficiency, probably due to their strong sorption capacity, and nutrient mining and therefore the low yields of maize grown in the soil were partly attributed to their deficiency. The use of Cu and Zn fertilizers improved maize yields appreciably. A greenhouse experiment estimated approximately a level of 10 kg Cu ha^{-1} and 8 kg Zn ha^{-1} to be optimum in Akpabuyo soil. Similarly, in the field experiment, Cu and Zn fertilizers significantly improved grain yields and contents of maize. The application of Cu fertilizer yielded maximum grain yield at the rate of 10 kg ha^{-1} while, Zn fertilizer produced maximum grain yield when Zn was applied at 8 kg Zn ha^{-1}. Accordingly, the rate of 10 kg Cu ha^{-1} and 8 kg Zn ha^{-1} are recommended in this soil to ensure that the yield potentials of maize is reached. Research should be undertaken on the chemistry and adsorption of Cu and Zn in Akpabuyo soil to identify the adsorption or retention capacity of this soil. Further research should be conducted to evaluate the potentials of these nutrients with other crops like roots and tubers in other areas of coastal plain sand derived soil.

Table 1: 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 kg^{-1}	12.23	Low
4	Total N	%	0.19	low
4	Cation exchange capacity	cmol kg^{-1}	16.89	Low
5	Exchangeable Ca	cmol kg^{-1}	3.60	Medium
6	Exchangeable Mg	cmol kg^{-1}	2.04	Medium
7	Exchangeable K	cmol kg^{-1}	1.34	High
8	Exchangeable Na	cmol kg^{-1}	0.15	Low
9	Exchangeable acidity	cmol kg^{-1}	1.30	-
10	HCl-extractable Cu	mg kg^{-1}	0.26	Low
11	HCl-extractable Zn	mg 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	

Table 2: Effects of Cu levels on maize dry matter (DM) yields, Maize grain yield **concentration and uptake of Cu in greenhouse experiment**

Cu levels (Kg ha^{-1})	DM yield g $plant^{-1}$	Cu concentration in plant mg kg^{-1}	Cu uptake mg $plant^{-1}$	Maize grain yield (t ha^{-1})	Cu conc. in grain (mg kg^{-1})
0	6.82	5.63	0.38	1.26	17.4
2	10.66	6.28	0.67	1.49	19.1
4	14.93	6.71	1.00	2.50	22.8
6	15.26	7.25	1.11	3.62	25.3
8	16.01	9.49	1.52	3.76	27.0
10	17.69	8.73	1.54	4.66	35.9
12	16.52	7.85	1.30	3.52	24.5
$LSD_{0.05}$	1.86	1.03	0.2	1.16	9.2
CV%	10.7	12.8	10.8	6.6	8.2

Table 3: Effects of Zn levels on maize dry matter (DM) yields, concentration and uptake of Zn in greenhouse experiment

Zn levels (Kg ha^{-1})	DM yield g $plant^{-1}$	Zn concentration in plant mg kg^{-1}	Zn uptake mg $plant^{-1}$	Maize grain yield (t ha^{-1})	Zn conc. in grain (mg kg^{-1})
0	5.6	3.15	0.18	1.55	16.3
2	9.45	4.58	0.43	3.11	19.8
4	14.08	6.06	0.85	4.25	21.7
6	19.63	7.15	1.40	5.19	22.9
8	17.2	10.4	1.79	5.23	32.1
10	16.79	9.71	1.63	4.88	24.1
12	16.14	8.15	1.32	4.64	23.5
$LSD_{0.05}$	3.28	1.25	0.37	1.92	5.51
CV%	12.8	32.2	39.5	8.94	10.05

REFERENCES

Bray, R. H., and Kurtz, N. T. (1945). Determination of total organic and available form of P in the soil. Soil Sci. 59: 39-45.

Chapman, H. D. and Pratt, P. F. (1961). Ammonium Vandate-Molydate method for the determination of phosphorus. In: Metods of Analysis for Soil, Plants and Water. Pp: 184-203.

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, Nigeria . pp. 89.

Enwezor, W. O., Ohiri, O. C., Opuwaribu, E. E. and Udo , E. J. (1990). A review of fertilizer use on crop in Southeastern zones of Nigeria (in five vols.) (FFDD eds). Boboma Publ. Ibadan, 47-70 pages.

Enwezor, W. O., Udo, E. J. and Sobulo, R. A. (1981). Fertility status and productivity of acid sands. In: Acid sands of Southeastern Nigeria. Mono. No. 1. Soil Science Society of Nig. 56-73 pages.

FFDD (Federal Fertilizer Distribution Department) (2002). Fertilizer use and Management practices for crops in Nigeria. Aduayi, E. A., Chude, V. O., Adebusuyi, B. A. and Olayiwola, S. O. (eds). Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria.123 p.

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

Jones, J. B. and Eck, H. V. (1973). Plant analysis as an aid in fertilizing corn and grain sorghum. In: L. M. Watsh and J. B. Beaton (eds). Soil testing and plant analysis. SSSA, Madison WF. P. 349-364.

Juo, A. R. S. (1979). Selected Methods for Soil and Plant Analysis. IITA Manual Series No. 1

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.

Landon, J. R. (1991). Booker Tropical Soil Manual. A Handbook for soil Survey and Agricultural Land Evaluation in the Tropics and sub Tropics. Longman Sci. and Techn. Publ., Harlon, UK.

Lisuma, J. B., Semoka, J. M. R. and Semu, E. (2006). Maize yield response and nutrient uptake after micronutrient application on a Volcanic Soil. Agron. J. Madison, W. I., 98: 402-406.

Mkemzie, R. H. (2003). Soil and plant Nutrients. Agricultulture, food and Rural Development. Pp:1-4.

Nelson, D. W. and Sommers, L. E. (1982). Organic Carbon. In: Page A.L. (ed). Method of soil analysis. No. 9. ASA Inc. Soil Science Society of American: Madison Washington D.C. PP. 570-571.

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.

Purseglove, J. W. (1988). Tropical Crops. Monocotyledons. Longman Sci. Tech Publ., Harlow, UK.

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.

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. 634 pages

Udo, E. J. and Fagbami, A. A. (1979a). The profile distribution of total and extractable Zn in selected Nigerian Soils. In: Commun Soil Science and Plant Analysis. 10(8): 1141-1161.

USDA (2006). Keys to Soil Taxonomy (10th Ed). United States Department of Agriculture, NRCS Soil conservation service, Washington D.C.

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