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Extractable Zinc and Copper in Hydromorphic Soils Developed on Basement Complex Rocks and Sedimentary Rocks in Niger State, Nigeria

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Abstract
The growing awareness of the enormous potential of hydromorphic soils (fadama) and the realization of their potentials necessitates taking the inventory of their micronutrients status. This study determined the status of extractable zinc (Zn) and copper (Cu) in two hydromorphic soils, developed on basement complex rocks (BCR) and sedimentary rocks (SR) in Niger State, Nigeria. Soil samples were collected randomly from two soil depths, 0-20 cm and 20-50 cm. Extractable Zn and Cu were extracted with 0.1 N HCl. The two soils are slightly acidic with high N, Ca, Mg and K fertility status, thus indicating their high potential for agricultural production. The soils have relatively high extractable Zn (> 4.17 mg kg^{-1}). Extractable Cu ranged from 0.47 mg kg^{-1} to 2.20 mg kg^{-1} in both soils. There was no significant relationship between the extractable Zn and Cu and sand, silt, clay, soil pH, organic carbon and ECEC. The two soils are currently sufficient in Zn and Cu for successful growth of most crops.
***Key words*: Basement complex rocks, sedimentary rocks, micronutrients and hydromorphic soils.**

Introduction

Micronutrients are not applied regularly to the soil in conjunction with common fertilizers, yet about two to six times in quantity of these elements are removed annually from the soil than applied to it (FAO, 1983). However, the intensification of cropping practices and adoption of high yielding cultivars which have high micronutrients demand have led to increased demand for micronutrients (Fageira *et al*., 2002). These have resulted in the manifestation of the deficiencies of micronutrients on crops and in soils in many part of the world (Sims and Johnson, 1991). In Nigeria, the deficiencies of micronutrients have started manifesting, due to reduction in length of fallowing, intensification of cropping on limited land available for farming, planting of crop varieties with high nutrients requirement and the use of high-analysis fertilizers with little or no micronutrients (Kparmwang *et al*., 1998; Adeboye, 2011). Studies on the micronutrients, which have been on the increase due to increasing manifestation of their deficiencies, have shown low levels of micronutrients in a range of soils including soils on basement complex rocks (Lombin, 1983a,b; Kparmwang *et al*., 1998) and soils developed on sedimentary rocks (Kparmwang and Malgwi, 1997).

The few studies on micronutrient levels in the soils in Nigeria have been mainly restricted to well drained arable lands. Zinc has been reported to be probably the most deficient micronutrient in savanna soils (Lombin, 1983a). Deficiency of Zn has been reported on basaltic soils in northern Guinea savanna (Kparmwang *et al*., 1998) and on some forest soils in the southern Guinea savanna (Samndi *et al*., 2007). Extractable Zn and Cu have been reported to be adequate in some hydromorphic soils developed on different parent materials in southern Nigeria (Aghimein, 1989) and lower Gongola river basin (Adeboye, 2011). Other investigations have revealed the deficiency of Cu in Ultisols derived from basement complex rocks in northern Guinea savanna (Mustapha and Singh, 2003) and in soils developed on sandstone and shale in the Benue valley (Kparmwang *et al*., 2000).

The hydromorphic soils (fadama) of Nigeria have enormous potential for food production, especially rice, which the country spends a huge amount on its importation. Niger State of Nigeria has 110,000 ha of fadama soils equivalent to about 3.5 % of its total land area (Gwarry, 1995), where crops are currently cultivated all year round under low intensity subsistence agriculture. In order to successfully realize the full potentials of these hydromorphic soils, there is the need to take an inventory of their nutrient status including micronutrients. The information will provide the basis for making informed decision with respect to fertilizer use and other soil management practices. This study was conducted to investigate the extractable Zn and Cu status of two hydromorphic soils developed on two parent materials, basement complex rocks (BCR) and sedimentary rocks (SR) in Niger State of Nigeria and the relationship between them and some soil properties.

Materials and Methods

The study area

Niger State lies approximately between latitudes 8° 10' and 11° 31' N and longitudes 4° 30' and 7° 15' E in the Guinea savanna agroecological zone of Nigeria. Geomorphologically, Niger State is covered by two major rock formations, that is, the sedimentary rocks (SR) to the south and basement complex rocks (BCR) to the north. Niger State experiences two distinct seasons (wet and dry). The annual rainfall varies from 1600 mm in the south to about 1200 mm in the north usually spread between the months of May and October. Mean annual temperature is high throughout, about 32 °C with peaks in the months of March to June.

Two sites namely Gidan-Kwano and Bida representing BCR and SR formations respectively were selected for the study. Gidan-Kwano is located on latitude 09° 31' N and longitude 06° 27' E and agroecologically falls within the sub-humid-Minna-Kaduna-Kafanchan High Plains consisting mainly of gently undulating high plains developed on BCR with poorly drained soils, Gleyic Luvisols and Eutric Fluvisols, occurring in the bottomlands (Ojanuga, 2006a). Bida is located on latitude 09° 08' N and longitude 06° 02' E and lies within the sub-Humid Central Niger-Benue Trough agroecological zone of Nigeria which is characterized by an extensive flat to very gently undulating lowlands with broad interfluves over very deep weathered Nupe sandstones. The lowland soils are poorly drained grey soils, Dystric Fluvisols and predominantly cropped to rice (Ojanuga, 2006a).

Soil sampling and analysis

Soil samples were collected randomly from the two hydromorphic soils, from two depths, 0-20 cm and 20-50 cm. Ten soil samples from each depth in the two soils, were collected to give a total of 40 soil samples, for laboratory analysis of extractable Zn and Cu. Sub-samples were taken from each of the 10 samples, for each depth and location, bulked together to form a composite sample and analysed for physicochemical properties. The soil samples were air-dried, gently crushed and routine analyses carried out in the laboratory following the procedures described in ISRIC/FAO (2002). Briefly, particle size analysis was determined by hydrometer method. The soil pH in 1:2.5 soil/water suspensions was measured with pH meter and organic C by Walkley-Black method. Total nitrogen (TN) was determined by Kjeldahl digestion procedure. Exchangeable bases, Ca^{2+}, Mg^{2+}, K^+ and Na^+ were extracted with 1N NH_4OAc. Calcium and Magnessium in the extract was determined using atomic absorption spectrophotometry while K^+ and Na^+ were determined by flame photometry. Exchangeable acidity was determined by titration with standard NaOH. Effective cation exchange capacity (ECEC) was determined by summation method. The available Zn and Cu were extracted with 0.01 N HCl and amount in extract determined using AAS.

The mean values and standard error of the micronutrients were computed. Paired t-test was used to compare the means and where significant separated at 5 % level, unless otherwise stated. Pearson correlation analysis was carried out to determine the relationship between the micronutrients and some soil properties. All analysis were carried out using SPSS 16.0 (SPSS, 2007).

Results and Discussion

Physicochemical properties

The results of some physicochemical properties of the soils are shown in Table 1. The interpretation of some chemical properties was made according to Enwezor *et al*. (1989) and Esu (1991).

The particle size analysis showed that most of the horizons of the two soils have sandy clay loam texture. The two soils showed decrease in sand content with soil depth while the distribution of silt and clay also differed. Silt was lower at the surface of the soils of BCR relative to soils of SR formations. The silt content in soils of BCR increased with soil depth, while in the SR, it decreased very slightly with soil depth. On the other hand, clay was higher at the surface of soils of BCR compared to the soils of SR and the clay content decreased with soil depth. Furthermore, the soils on SR formation showed evidence of downward migration of clay. This study could not establish that the differences observed in the physical properties of the soils, was due to their parent materials, however, Ojanuga (2006b) generally described fadama soils to vary widely in their characteristics.

All the soils have pH ranging from slightly acidic to slightly neutral. In both soils, pH increased with soil depth and the values were within an established favourable range, 5.2 to 8.0 for most agricultural crops and also for optimum availability of Zn and Cu (Lake, 2000). The soil organic carbon (SOC) was rated medium to low in BCR and low in SR. The medium to low SOC contents of the two soils might be due to sparse vegetation cover of savanna soils coupled with annual bush burning which is a common practice in the savanna agroecological zone of Nigeria. Also, the rapid mineralization of organic matter and inadequate return of crop residues to the soil could be responsible for the low OC contents. Total nitrogen (TN) in the soils was rated high in the two soils. The available phosphorus (P) was rated high in surface soils of BCR and medium at the subsurface, while that of SR soils was rated medium at the surface and low and subsurface. Although, the available P was significantly higher ($P>0.05$) in BCR relative to SR derived soils, both sites however showed decrease in available P with increasing soil depth. The decreased values of available P with increasing soil depths might be as a result of its low mobility in the soil. Generally, calcium (Ca) was the dominant cation and its concentration was higher in the soils of SR than in the BCR followed by magnessium (Mg). The trend of distribution of Mg and Ca in the soils investigated was similar to the findings of Adegbite and Ogunwale (1994) that also reported Ca as the dominant cation in the fadama soils of Abugi along the bank of River Niger under the same sub-humid central Niger-Benue trough agroecological zone of Nigeria. The potassium (K) values were 0.49 and 0.61 $cmol_{(+)}$ kg^{-1} for BCR and 0.54 and 0.59 $cmol_{(+)}$ kg^{-1} SR for surface and subsurface soils respectively. All the exchangeable bases in the soils were rated high in the two soils. The fadama soils are usually fertile due to seasonal deposition.

Extractable Zinc

The extractable Zn of all the soils ranged from 4.17 mg kg^{-1} to 7.40 mg kg^{-1} with the highest value of 7.40 mg kg^{-1} obtained in the surface soil of the soil on SR (Table 2). The values are above the critical level of 0.8 mg kg^{-1} (Lindsay and Norvell, 1978) and also above the critical range of 0.2-2.0 mg kg^{-1} reported by Sims and Johnson (1991). The extractable Zn values are rated as medium to high (Table 3). The soils could therefore be regarded as being adequate in extractable Zn. Adequate extractable Zn have been reported for similar hydromorphic soils in Nigeria by other workers (Aghimien, 1989; Adeboye, 2011). The values are similar to those reported for other soils developed on sedimentary rocks in the Benue valley (Kparmwang *et al*., 2000). The relatively high values in all the soils may be partly attributed to the relatively high clay particle content in all the soils and their reaction. Soils with high clay particle content have been reported to be rich in Zn (Lombin, 1983a). Availablity of zinc is usually enhanced at the pH range of all the soils (Lake, 2000).

The subsurface soils of the two parent materials which had higher soil pH than the surface soils (Table 1) also had higher extractable Zn probably due to the reason given earlier. The subsurface soil of the soil developed on SR which had the highest soil pH of 7.3 also had the highest extractable Zn value of 7.4 mg kg^{-1}. Although hydromorphism is common in these soils, soils that are developed from old parent rocks, such as basement complex rocks that have been subjected to conditions of deep weathering and soil leaching favor translocation of clay and soil nutrients while in sedimentary rocks parent materials, some that have undergone various severe weathering cycle also exhibit in parts, downward clay and low nutrients movement (Aghimien, 1989). These may be another reason for the high extractable Zn of subsurface soils compared to the surface soils in both soils.

Extractable Copper

The extractable Cu contents of the soils are shown in Table 2. Similar to Zn, the extractable was relatively high. The values compare favourably to those reported for other Nigerian hydromorphic soil (Aghimien, 1989; Adeboye, 2011), but higher than that in Nigerian soils in general (Kparmwang *et al*., 1994; Kparmwang et al., 2000; Mustapha and Singh, 2003). The extractable Cu in both soils was above the critical available level of 0.2 mg kg^{-1} (Lindsay and Norvell, 1978). Based on a three tier system of "low", "medium" and "high" rating (Table 3), all the soils are rated as high except, the subsurface soil of the soil on SR, which is in the medium range. All the soils could therefore be regarded as adequate in available Cu.

The fairly high content of extractable Cu may be attributed probably to the parent material from which the soils were formed having high content of Cu-bearing minerals, such as cuprite, since no significant relationship was found between extractable Cu and pH, SOC, and clay (Table 4). Cu accumulation in soils is usually enhanced by low pH, high SOC and clay particle contents (Brady and Weil, 2003).

Relationship between micronutrients and soil properties

The relationship between the extractable Zn, and Cu and some soil properties are shown in Table 4. The extractable Zn and Cu did not correlate significantly (P> 0.05) with all the soil properties. The lack of relationship between extractable Zn and Cu and soil properties may be partly due to irregular distribution patterns of these soil properties in the two horizons sampled. Another reason may be due to the extractant, 0.1 N HCl, used in the extraction. Aghimien (1989) reported similar results in some hydromorphic soils developed on different parent materials in southern Nigeria with 0.1 N HCl extraction but obtained significant relationship, when 0.005 M DTPA was the extractant. These results suggest that availability of Zn and Cu in these soils are probably influenced by some undefined properties of the soils. Significant relationship have been obtained between total and extractable forms of Zn and Cu in similar hydromorphic soils developed on basement complex rocks and sedimentary rocks in Nigeria by other authors (Fagbami *et al*., 1985; Aghimien, 1989; Adeboye, 2011).

Conclusion

The two hydromorphic soils have high fertility status thus confirming their enormous potential for agricultural production. The soils are currently adequate in Zn and its deficiency will not pose problem in the immediate future. This infers that the parent materials may be rich in Zn-bearing minerals. Copper deficiencies are not expected currently in these soils. But with intensification of cropping, after a few years, there will be the need to reinvestigate the Cu status of the soils especially the soil on sedimentary rocks with fairly adequate amount of extractable Cu.

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Table 1: Some physicochemical properties of the soils

Parent material	Depth (cm)	Sand	Silt	Clay	Textural Class	pH 1:2.5 (H_2O)	Org. C.	TN	Avail. P. (mg kg^{-1})	Exch. Acid.	Exch. Bases Ca	Mg	K	ECEC
							(g kg^{-1})			(cmol kg^{-1})				
Basement Complex Rocks	0-20	640	130	230	Sandy clay loam	6.4	13.40	2.33	21	0.52	2.09	1.22	0.49	15.21
	20-50	620	210	170	Sandy loam	7.3	7.50	1.92	13	0.56	2.02	0.98	0.61	16.70
Sedimentary Rocks	0-20	600	150	250	Sandy clay loam	6.5	7.70	1.94	16	0.55	2.57	1.02	0.54	19.54
	20-50	600	150	250	Sandy clay loam	7.0	8.80	1.97	7	0.57	3.80	1.82	0.59	25.96

Table 2: Extractable zinc and copper of the soils under different parent materials

Parent material	Depth (cm)	Zn (mg kg^{-1})	Cu (mg kg^{-1})
Basement complex rocks	0-20	4.90 (1.07)*	1.73 (0.48)
	20-50	6.43 (1.17)	2.20 (0.44)
Sedimentary rocks	0-20	4.17 (1.47)	1.00 (0.24)
	20-50	7.40 (1.90)	0.47 (0.17)

*Standard deviation of means in parenthesis

Table 3: Critical limits for interpreting levels of analytical parameters*

Parameter	Low	Medium	High
Ca^{2+} (cmol$_{(+)}$ kg^{-1})	< 2	2 – 5	> 5
Mg^{2+} (cmol$_{(+)}$ kg^{-1})	< 0.3	0.3 – 1	> 1
K^{+} (cmol$_{(+)}$ kg^{-1})	< 0.15	0.15 – 0.3	> 0.3
Org. C (g kg^{-1})	< 10	10 – 15	> 15
Total N (g kg^{-1})	< 0.1	0.1 - 0.2	> 0.2
Avail. P (mg kg^{-1})	< 10	10 – 20	> 20
Zinc (mg kg^{-}1)	< 0.8	0.8-2.0	> 2.0
Copper (mg kg-1)	< 0.2	0.2-1.0	> 1.0

*Zn and Cu adapted from Lindsay and Norvel (1998) and Sims and Johnson (1991). Others adapted from Enwezor *et al*. (1989) and Esu (1991).

Table 4: Pearson's Correlation coefficient of Zn and Cu with some soil properties

	Extractable Zn	**Extractable Cu**
Sand	-0.074NS	0.278NS
Silt	-0.156NS	0.208NS
Clay	0.157NS	-0.396NS
pH	0.263NS	0.066NS
Org. C	0.189NS	0.069NS
ECEC	-0.035NS	-0.060NS

NS- Not significant.