STATUS OF EXTRACTABLE MICRONUTRIENTS IN RELATION TO OTHER SOIL PROPERTIES OF GABARI DISTRICT, ZARIA, NIGERIA

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ABSTRACT

*Micronutrients are essential elements for normal growth of plants, that are needed in little amount. The contents of available iron (Fe), manganese (Mn), zinc (Zn), copper (Cu) and boron (B) were determined in seventeen soil samples collected from genetic horizons of six pedon in northern Guinea savanna zone of Nigeria using standard methods. The mean content of available Fe, Mn, Zn, Cu and B was 53.75 mg kg^{-1}, 13.16 mg kg^{-1}, 6.69 mg kg^{-1}, 2.45 mg kg^{-1}and 1.69 mg kg^{-1}respectively. Zn was observed to be deficient in 45% of the sub-soils where trace amounts were recorded while other micronutrients were adequate in all the sub-soils. Soil clay content and pH significantly correlated positively with Cu at r= 0.616** and r=0.485* respectively. Organic carbon (OC) correlated positively with B (r = 0.696**), Fe (r = 0.483*) and Mn (r = 0.509*). There were also significant relationships among the micronutrients; Fe correlated with all the other micronutrients. Generally, the soils were sufficiently supplied with available micronutrient, but for sustainable crop production application of farm yard manure and crop residue will be required.*

Keywords: Status, Soil Micronutrients, Soil Macronutrient, Pedons.

INTRODUCTION

Soil plays a major role in determining sustainable productivity of an agro-ecosystem. The sustainable productivity of a soil depends mainly on its ability to supply essential nutrients to growing plants. Micronutrients are essential elements for normal growth of plants, that are needed in little amount (Fageria, 2007). If these elements are insufficient, plants may suffer from physiological stresses caused by inefficiency of several enzymatic systems and other related metabolic functions (Baybordi, 2006). The deficiency of micronutrients has become a major constraint to productivity, stability and sustainability of some Nigerian savanna soils (Lombin, 1983a; 1983b; 1985; Sadiqq *et al.*, 2008; Ibrahim and Abubakar, 2013). Low levels of available Zn and B have been reported in soils of northern Guinea savanna (Enwezor, *et al.*, 1990; Oyinlola and Chude, 2010).

Introduction of hybrid crops in Nigeria agriculture and change in agricultural systems from fallow/shifting cultivation to intensive and continuous crop production to feed the increasing human population have forced farmers to use high dose of NPK (nitrogen, phosphorus, and potassium) fertilizer (Oyinlola and Chude, 2010). In recent years, large hectares of arable land in

Nigeria were reported to be deficient in micronutrients and many of these deficiencies were brought about by the continuous use of inorganic fertilizers; particularly N, P, and K by farmers, limited use of organic manures as well as non-recycling of crop residues (Ibrahim *et al*., 2011). Oyinlola and Chude (2010) have also reported that soils of Samaru and Kadawa in northern Guinea Savanna are deficient in Zn and B.

Understanding micronutrient levels in soils of Gabari is imperative; not only for improvement of soils data bank, but also for agricultural planning, development and identifying areas where micronutrient fertilizers will be useful for higher crop yield and economic return. The objective of this study was to determine the extractable Fe, Mn, Zn, Cu, and B in relation to other soil properties of the study area.

STUDY AREA

This study was carried out in Gabari District of Sabon Gari Local Government Area of Kaduna State, Nigeria ($11^{0}06'50''$N - $7^{0}40'22''$E) (Fig. 1) characterized by northern Guinea savanna vegetation type (Yakubu, 2004). The area lies within the tropical savanna (Aw) climate type with distinct wet and dry season (Kowal and Knabe, 1972). It is characterized by long dry season from November through March while the wet season last from May to October with a mean annual rainfall of 1100mm. The temperature fluctuates within a range of 22^{0}C during cold nights to over 38^{0}C during the hot days. The relative humidity during dry season is about 15% and reaches up to 60% during the rainy season (Kowal and Knabe, 1972). Geologically the area lies within the high plains of northern Nigeria characterized by landforms which consist of inselbergs and pediment landscape overlying the basement complex which are nearly level to gentle undulating plains (Yakubu, 2004).

MATERIALS AND METHODS

Soil Sampling

The study involved a detailed soil survey using rigid-grid method (100 m × 100 m) on a 70 ha land. Soil mapping units were mapped based on soil colour, texture, depth and drainage. In each soil unit, two profile pits were dug and examined according to Soil Survey Staff (2010). Seventeen (17) soil samples were collected from all genetic horizons of the six (6) profile pits dug to characterize the three mapping units. The soil samples collected were stored in properly labeled polythene bags and taken to the laboratory for analyses. In the laboratory, the soil samples were air dried crushed and sieved with a 2 mm sieve. The less than 2 mm samples were used for all laboratory analyses.

Laboratory Analyses

Particle size distribution was determined by the hydrometer method (Agbenin, 1995). Soil pH was measured in water using glass electrode pH meter (Agbenin, 1995).

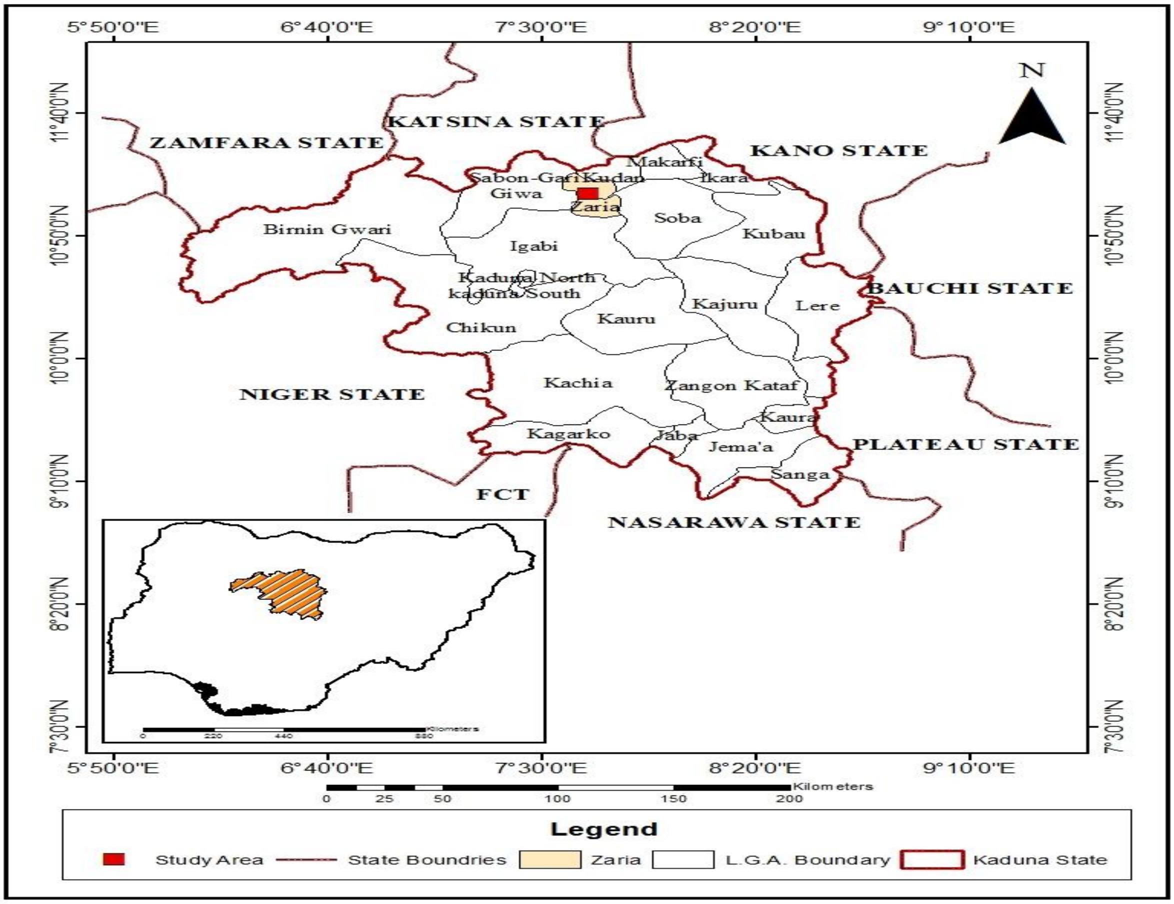

Fig. 1: Location of the study area in Kaduna State, Nigeria

Organic carbon was determined by the dichromate wet oxidation method of Walkley and Black (Nelson and Sommers, 1982). Available P was determined using Bray No 1 method (IITA, 1979). Total N was determined by the microkjeldahl method (Bremner and Malvaney, 1982). The cation exchange capacity (CEC) was determined by saturating the soil with 1N ammonium acetate solution (Agbenin, 1995). The extractable micronutrients: Zn, Cu, Fe and Mn were extracted with 0.1M HCl solution (Osiname *et al.*, 1973) and determined on an atomic absorption spectrophotometer (AAS). Available-B was extracted with cold water and determined colorimetrically by Azomethine-H method (Agbenin, 1995)

Statistical Analysis: Pearson linear correlation analysis was used to show the relationships between micronutrients and other soil properties.

RESULTS AND DISCUSSION

Three soil mapping units were delineated and designated as GBI, GBII and GBIII. The range and mean values of physical and chemical properties of the soil units are shown in Table 1. The soils were rated using the critical limits recommended by Malgwi (2007). The soil texture ranged from loam to sandy clay loam. The soil reaction was slightly acidic to neutral (pH 6.4–6.9); these values are within the pH requirement of most arable crops for nutrient uptake (Brady and Weil, 1999). Generally, organic carbon (OC), available phosphorus (Ap) and total nitrogen (TN) were rated low according to the rating of Malgwi (2007) on critical value of these nutrients for crop production. Jones and Wild (1975) have also reported low values of OC, Ap and TN in Nigerian savanna soils. Cation exchange capacity (CEC) were rated medium to high (7.5 -13.9 $cmolkg^{-1}$) based on the ratings of Malgwi (2007). The values were greater than the critical value of 4.0 $cmolkg^{-1}$ needed to retain most cations against leaching in the highly weathered sandy soils as suggested by Sanchez (1976).

Table 1 Ranges and mean values of physical and chemical properties of the Soils of Gabari District

Soil Parameters	Range	Mean
Silt (%)	24 – 56	40
Clay (%)	9 – 37	23
pH	6.4 – 6.9	6.65
OC gkg^{-1}	1 – 8.8	4.9
TN gkg^{-1}	0.07 – 0.28	0.18
Ap ($mgkg^{-1}$)	1.75 – 5.08	3.42
CEC ($cmolkg^{-1}$)	7.5 – 13.9	10.7

Available micronutrients in the pedons of the soils

Iron (Fe)

Mean extractable Fe content in the soils was 39.45$mgkg^{-1}$, 59.57$mgkg^{-1}$ and 48.59$mgkg^{-1}$on surface horizon of mapping units GBI, GBII and GBIII. The subsoil values were 23.53$mgkg^{-1}$, 22.07$mgkg^{-1}$ and 43.61$mgkg^{-1}$. The soils were rated very high in Fe content (> 4.5 $mgkg^{-1}$) based on rating of Malgwi (2007). Higher concentration of Fe obtained in the study could be as a result of neo-formed iron from transformation product of biotite mica. This could result from geological formation of the study sites, being basement complex in origin. Generally, extractable Fe decreased down the profiles (Table 2) which could be as a result of decrease in organic carbon.

Therefore, the soils were sufficiently high in Fe with very little chances of deficiency. This conforms with the report of Odunze and Kureh, (2009) and Hussaini (2011) in the soil of northern Guinea savanna, Ibrahim and Abubakar (2013) in soils of Gombe State who reported high Fe content in soil of their study area; though, the present study recorded higher values than that of previous researches.

The presence of Fe in high concentrations in soils could lead to its precipitation and accumulation and upon complex chemical reactions, lead to the formation of plinthites (laterite) which could restrict root penetration and lead to poor drainage. For instance, the poor drainage in GBIII could be as a result of the presence of plinthite at the subsoil (Ibrahim and Abubakar, 2013).

Manganese (Mn)

The mean values of extractable Mn in surface soils were 16.44$mgkg^{-1}$, 10.45$mgkg^{-1}$ and 14.07$mgkg^{-1}$ in soil mapping units GBI, GBII and GBIII. The subsoil values were 5.56$mgkg^{-1}$, 7.1$mgkg^{-1}$ and 10.32$mgkg^{-1}$. The soils were rated high in Mn content as the critical value of Mn ranges between 1 $mgkg^{-1}$ for low and 5 $mgkg^{-1}$for high (Malgwi, 2007). Extractable Mn in the soils decrease with depth which could be as a result of decrease in OC similar to Fe (Table 2).

However, the moderate to high Fe and Mn content of the soils may account for the observed Fe and Mn oxides nodules and concretions found in the sub soils. These confirm report of Odunze and Kureh (2009) who also reported Fe and Mn concretions in the sub soils of their study area.

Copper (Cu)
Extractable Cu content in the soils averaged 2.1mgkg^{-1}, 2.13mgkg^{-1} and 1.96mgkg^{-1} in soil mapping units GBI, GBII and GBIII. Subsoil values were 2.15mgkg^{-1}, 2.45mgkg^{-1} and 2.05mgkg^{-1}.

Table: 2 Profile Distributions of Micronutrients in Gabari

Soil Mapping Units	Horizon	Depth (cm)	Fe	Mn	Cu	Zn	B (mg/kg)
	GBIP1	Lat. N11^0 06′ 57"Long. E7^0 40′ 28"			Elevation 640m		
GB I	Ap	0 – 21	22.68	9.30	2.23	2.90	1.70
	Bt1	21 – 114	17.80	4.96	2.07	2.16	1.36
	Bt2cv	114 -140	20.58	2.73	2.18	2.41	1.36
	GBIP2	Lat. N11^0 07′ 07"Long. E7^0 40′ 30"			Elevation 635m		
	Ap	0 – 40	56.22	23.58	1.96	4.66	2.44
	Bt1	40 – 70	17.80	2.80	2.07	1.18	0.95
	Bt2	70 – 140	37.92	11.73	2.29	12.68	1.36
	GBIIP1	Lat. N11^0 07′ 0"Long. E7^0 40′ 40"			Elevation 624m		
GB II	Ap	0 – 50	28.78	9.63	2.18	4.00	1.36
	GBIIP2	Lat. N11^0 07′ 05"Long. E7^0 40′ 32"			Elevation 624m		
	Ap	0 -40	90.36	11.26	2.08	2.65	1.36
	2Bt1	40 – 120	19.02	5.37	1.85	Trace	0.75
	GBIIIP1	Lat. N11^0 07′ 19"Long. E7^0 40′ 30"			Elevation 625m		
GB III	Ap	0 – 27	60.48	14.64	2.07	2.89	1.97
	Bt1	27 -75	34.87	10.04	1.96	Trace	1.08
	Bt2	75 – 148	37.92	9.30	2.07	Trace	1.97
	Bt3c	148 – 165	17.15	3.40	1.85	1.67	1.70
	GBIIIP2	Lat. N11^0 07′ 19"Long. E7^0 40′ 39"			Elevation 623m		
	Ap	0 – 42	36.70	13.50	1.85	3.14	1.29
	Bt1	42 – 70	38.53	16.67	1.96	Trace	0.95
	Bt2	70 – 120	51.34	11.60	2.29	0.69	1.15
	Bt3c	120 – 170	81.82	10.92	2.18	Trace	1.36

Source: Authors' Analysis

The values were rated high. Extractable Cu content increased with increase in depth. This trend may be attributed to better retention of Cu with increasing clay content. These results corroborate the earlier report of Raji (1995) and Malgwi (2001). Odunze and Kureh (2009) also reported high content of Cu in Zaria soils but Shobayo (2010) reported trace amount but attributed low Zn content to nature of parent materials.

Zinc (Zn)

Extractable Zn in surface soils averaged 3.78mgkg^{-1}, 3.33mgkg^{-1} and 3.02mgkg^{-1}in soil mapping units GBI, GBII and GBIII. Subsoil values were 4.61mgkg^{-1}, 1.67mgkg^{-1} and 1.18mgkg^{-1}. Extractable Zn was rated high since it was greater than the critical level of 1.0 mgkg^{-1}(Malgwi, 2007). The values of extractable Zn in the soils decreased irregularly down the profile and this could be attributed to low amount of OC in the underlying soil. This confirms the report of Hussaini (2011) who also reported high content of extractable Zn in Zaria.

Available Boron (B)

The available B found in surface soils averaged 2.07mgkg^{-1}, 1.36mgkg^{-1} and 1.63mgkg^{-1} in soil mapping units GBI, GBII and GBIII respectively. Subsoil values were 1.26mgkg^{-1}, 1.19mgkg^{-1} and 1.37mgkg^{-1}across the soil mapping units respectively. The content of B was generally higher than the critical value of 0.4 mg kg^{-1} related by Wolf (1971). Available B within the study area was classified as medium to high based on the rating of Chude *et al.* (2004). The result obtained from this study was higher than 0.18 – 0.36 mg kg^{-1} reported by Lombin (1985b), 0.08 – 0.17 mg kg^{-1} obtained by Daudu (1989) and 0.04 - 0.28 mg kg^{-1} testified by Oyinlola and Chude (2010) for soils of northern guinea savanna. Boron content of the soils was higher in the surface horizon but was found to decrease with increasing depth which could be attributed to decrease in organic carbon down the soil horizon or depth.

Relationship between micronutrient and soil properties

All the investigated micronutrients (Fe, Mn, Cu, Zn and B) were influenced by selected soil environment. This confirms the report of Brady (1995) who also reported significant relationship between macro and micronutrient. Sand correlated positively with all the micronutrient except Cu and B as shown in Table 3. Silt correlated negatively with Cu and Zn, while Clay correlated negatively with all the micronutrient except Cu with a highly positive correlation ($r = 0.616^{**}$). This signifies that availability of micronutrients in the pedons was affected by texture. Kparmwang *et al*. (1998) also reported the influence of soil texture on availability of Zn and Cu in basaltic soil of Nigeria savanna.

Soil pH has been comprehensively identified as the single most important soil factor controlling the availability of micronutrients in soil (Yadav, 2011). Manganese (Mn) and iron (Fe) were negatively correlated with soil pH, whereas they were positively correlated with Cu (Table 3).This confirms report of Yadav (2011) who reported significant correlation between Mn, Fe, Cu and pH. Reduction in availability of Fe with increase in pH might be attributed to the conversion of Fe^{2+} to Fe^{3+} ions. At high pH, Fe may also precipitate as insoluble form ($Fe(OH)_2$). Similarly, with increase in pH, divalent form of Mn may convert into tri or tetravalent forms which are water insoluble; hence not readily available to plants (Yadav, 2011). Similar relationships were reported by Kparmwang and Malgwi (1997) and Ibrahim and Abubakar (2013).

OC correlated significantly with available Fe, (r = 0.483*), Mn (r = 0.509*) and B (r = 0.696**) (Table 3). This shows that a large amount of organic bound Fe, Mn and B are available in the soils. The availability of micronutrients increase with increase in organic matter content might be ascribed to greater availability of chelating agents through organic matter decomposition.

Table 3: Simple correlation (r) between soil properties and micronutrients

	Sand	**Silt**	**Clay**	**pH**	**OC**	**TN**	**Ap**	**CEC**	**Fe**	**Mn**	**Cu**	**Zn**	**B**
Sand	1												
Silt	-0.71**	1											
Clay	-0.28	-0.48*	1										
pH	-0.54*	0.16	0.46	1									
OC	0.10	0.34	-0.59*	-0.21	1								
TN	0.27	-0.18	-0.09	0.07	0.28	1							
Ap	0.15	0.08	-0.29	-0.41	0.22	-0.06	1						
CEC	-0.18	0.14	0.03	0.07	-0.14	-0.12	0.03	1					
Fe	0.11	0.23	-0.46	-0.24	0.48*	-0.13	0.37	-0.01	1				
Mn	0.11	0.19	-0.41	-0.40	0.51*	-0.20	0.50*	0.11	0.57*	1			
Cu	-0.17	-0.29	0.62**	0.49*	-0.21	-0.22	-0.04	0.15	-0.03	-0.08	1		
Zn	0.43	-0.39	-0.01	-0.32	0.29	0.22	0.31	0.13	0.02	0.23	0.15	1	
B	-0.19	0.23	-0.07	0.003	0.67**	0.10	0.22	0.05	0.22	0.45*	0.12	0.24	1

Level of Significant
**= Highly significant
* = Significant

Similar relationships were reported by Kparmwang and Malgwi (1997) and Oyinlola and Chude (2010). Tisdale *et al.* (2003) reported that micronutrients form stable complexes with soil organic matter-components and that organically bound forms of the micronutrient cations are more available to plants than the inorganic forms; insoluble inorganic precipitates and those held in primary minerals. TN correlated negatively with Fe, Mn and Zn. Available phosphorus (Ap) significantly correlated positively with Mn (r =0.504*). The CEC which determines most exchange reaction in soils was observed to correlate positively with all the micronutrient except Fe. Clay and OC which correlated significantly positive with the micronutrients were in line with the findings of Lombin (1983b) and Yadav (2011) who reported that OC and clay are generally considered the mainstay of extractable micronutrients in the soil. Similarly, Balasubramanian *et al.* (1984) reported that the levels of many nutrients in savanna soils are intrinsically tied to the level of OC in these soils. The result obtained from this study confirms the report of Brady and Weil (2002) and Tisdale *et al.* (2003) that the availability of most micronutrients in soils depend on soil pH, OC content, adsorptive surfaces and other physical, chemical and biological conditions in the rhizosphere.

Relationship among the Micronutrients

Available Fe correlated with Mn (r = 0.569*) similar to report of Oyinlola and Chude (2010). Available Mn also correlated with available B (r = 0.448*). Buckley (1989) reported that the surfaces of secondary oxides of Mn control the behavior of certain trace elements by adsorption and specifically that Mn coatings on elastic particles attract Cu and Zn among others. The significant relationships among the micronutrients signify that their availability is controlled by similar pedogenic processes or factors (Kparmwang and Malgwi, 1997).

CONCLUSION

This study sought to evaluate the status of available micronutrients and their relationships with some macronutrients in soils of northern guinea savanna of Nigeria. Results obtained show that, out of the five micronutrients studied (Fe, Mn, Zn, Cu and B), only Zn was deficient in the subsoils where trace amounts were recorded. The significant relationship between micronutrients and soil properties show the importance of these soil properties (clay, pH, and OC) in the availability of micronutrients. Also, significant relationship among the micronutrients points to the fact that, their availability is controlled by similar factors. Generally, the soils were sufficiently supplied with available micronutrient, but for sustainable crop production, it is recommended that farmers in the study area apply farm yard manure and crop residue to improve overall fertility of the soils and maintain the availability of micronutrients.

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