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ASSESSMENT OF THE METALLIC MICRONUTRIENT ELEMENTS IN THE BENCHMARK SOILS OF SAVANNA REGIONS, NORTH-EAST NIGERIA.

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ABSTRACT

The status of metallic micronutrient elements extractable in 0.005M DTPA was assessed in 31 locations across the North-east Nigeria which comprises of six states (Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe). Composite surface (0-20cm) and sub-surface (20-50cm) soil samples were collected from areas having different parent materials, vegetation zones and soil texture. The soil samples were analyzed for available Cu, Fe, Mn and Zn following discrete procedures. Few important soil properties were also analyzed (particle size analyzes, soil pH, soil organic carbon, available phosphorus-Bray-1 P and total nitrogen). The soils were sandy to clayey in texture. Soil pH ranged from strongly acidic (pH 4.44) to slightly alkaline (pH 7.47) in both surface and subsurface soils. Soil organic carbon ranged from very high (3.18 mg/kg) to very low (0.09 mg/kg). The content decreased from Southern guinea savanna to Sahel savanna respectively. Available P in dilute acid fluoride (Bray-1 P) ranged from very high (24.5 mg/kg) to low (2.1 mg/kg) in both surface and sub-surface soils, while total nitrogen was generally low in most of the samples analyzed except in few. DTPA Cu was higher in clayey surface soils (0.143 mg/kg) and subsurface soils (0.36 mg/kg) than in the sandy surface (0.119 mg/kg) and subsurface soils (0.189 mg/kg) and the content increased with depth. The content was also highest in basalt and alluvium and lowest in Aeolian sand. Available Fe and Mn extractable in DTPA were higher in surface than in subsurface soils. Generally, both metals were abundant in the soils regardless of parent materials, vegetation, and texture and soil depth. Extractable Fe correlated negatively with available P (r = - 0.972**) and total N (r = - 0.700**), while Mn was related positively with pH (r = 0.382**) and negatively with Bray-1 P (r = - 0.852**). Available Zn extractable in DTPA was generally deficient in all the samples irrespective of soil parent materials, vegetation zones, and soil texture and soil depth. Available Zn correlated positively with organic carbon (r = 0.560**) but negatively correlated with percentage sand (r = - 0.613**). Results from the analysis indicated that areas represented by the majority of the soil samples were deficient in Zn extractable in DTPA. Available Cu was also probably deficient in the soils. However, Fe and Mn were found to be sufficient in the soils of the study area regardless of parent materials, vegetation zones or soil texture. Available micronutrients were generally low in soils developed on Aeolian sand deposits. DTPA extractable micronutrients also showed decreasing trend from the Southern Guinea savanna northward to the Sahel savanna.

INTRODUCTION

Even though soil and plant factors greatly affect the availability of metallic micronutrients to plants, problems associated with trace elements are often primarily due to deficiency or excess of the element in the parent material from which the soils of the area are formed. Parent material is therefore, one of the major factors controlling and determining the type, total amount and availability of micronutrient elements in the savanna soils (Chude *et al.,* 1993).

The major soil parent materials found in the Savanna region of North-eastern Nigeria include the recent aeolian sand deposits of the Sahel and Sudan savanna, basement complex found mainly in the Southern and Northern Guinea savanna, basalt found in the mountainous regions of Biu and Mambila plateau, Alluvium and lacustrine clay found in some parts of Northern Borno, Adamawa and Bauchi states (Bawden *et al.,* 1972; Shuaib *et al.*, 1997; Kwari *et al.*, 1999b). The region comprises of four major vegetation zones, Southern Guinea Savanna, Northern Guinea Savanna, Sudan Savanna and the Sahel Savanna respectively (Shuaib *et al.*, 1997).

Metallic micronutrient elements are constituents of minerals of igneous or sedimentary origin. They vary in their contents from soil to soil and from one parent material to the other. Nigerian soils derived from basic rocks such as basalt and amphiboles have higher content of micronutrients than those derived from acid granites and sandstones (Chude *et al*., 1993). Copper in particular shows a conspicuous difference in abundance between basalt and granite in igneous rocks. Manganese occurs in igneous rocks primarily in silicate minerals. Zinc is averagely abundant in mafic igneous rocks than in felcic igneous rocks (Krauskoff, 1972).

It is not so much the abundance or the total content of any of these micronutrient elements as its availability that is crucial to plants growth. The micronutrients in most soils are ordinarily insoluble and are not easily available to plants. There are established deficiencies of these micronutrient elements worldwide. The deficiency of Zn is apparently the prevalent, but those of Cu, Fe, and Mn have also occasionally been identified (Lopes, 1982).

In plants, there is specific functions micronutrient elements play. Copper is involved in chlorophyll formation and degradation of sugar and in the synthesis of protein in the chloroplast. Iron is capable of acting as electron carrier in enzyme systems that bring about oxidation-reduction reactions. Manganese is particularly essential for certain nitrogen transformations in microorganisms as well as in higher plants. Zinc plays a role in protein synthesis in the formation of some growth hormones and in the reproduction process of certain plants (Price *et al*., 1972; Brady and Weil, 2002; Agbede, 2009).

Consequently, a study on the status of the four major metallic micronutrient elements in the soils of Savanna region of North-east Nigeria was necessary to assess the status of available form of these micronutrient elements.

MATERIALS AND METHODS

Geographical location of the study area

The study was conducted in the region of North-eastern Nigeria. The study area comprised of six states; Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe. The study area lies between latitude 8^oN and 14^oN and longitudes 8^oE and 14^oE respectively. The sampling locations were selected to reflect the different soil parent materials from which the soils were formed (Aeolian sand, Alluvium, Basalt, Basement complex, and Sandstones). They were also selected to represent the four vegetation zones in the study area; Southern guinea savanna, Northern guinea savanna, the Sudan savanna and the Sahel savanna.

Soil sampling and sample preparation

Based on above factors (parent materials and vegetation zones), thirty-one (31) locations were selected across the zones from Monguno (Sahel Savanna) to Gembu on the Mambila plateau (Southern Guinea Savanna). Soil samples were collected from both surface (0-

20 cm) and subsurface (20-50 cm) using soil auger. Composite samples (4-10 sub-samples) were collected, thoroughly mixed and neatly packed and carried in new polythene bags. The soils were air-dried, crushed separately using wooden mortar and pestle and passed through 2 mm and 0.5 mm sieves depending on the size requirement of analysis.

Laboratory Analysis

Each sample was analyzed for some few important properties of the soil and individual metallic micronutrient elements (Cu, Fe, Mn and Zn). The hydrometer method was used for particle size analysis (soil texture), soil pH was measured in distilled water in the ratio of 1:2.5 H_2O using glass electrode pH meter (model 5). Percentage organic carbon was determined by the Walkley and Black oxidation method as described by Jackson (1982). Dilute acid fluoride was used to extract phosphorus from the soil samples as described by Bray and Kurtz (1945), while total nitrogen was analyzed by Macro-Kjeldahl method as described by Jackson (1982).

The four metallic micronutrient elements (Cu, Fe, Mn and Zn) were extracted from the soil sample by 0.005M DTPA as proposed by Lindsay and Norvell (1978). The extracts were then analyzed for the individual micronutrient element by Atomic Absorption Spectrophotometer (AAS), under different wavelengths.

Statistical Analysis

Correlation coefficient between the metallic micronutrient elements and some few important soil properties were determined using simple linear correlation analysis. The soils were also grouped \according to soil parent materials, vegetation zones and soil texture using simple descriptive statistics.

RESULTS AND DISCUSSION

Some selected soil properties

Tables 1-3 show the status of metallic micronutrient elements and some selected soil properties. The soils of the study area varied in texture from loamy sand to clay in both surface and subsurface soils. Sandy soils (loam sand to sandy loam) constituted 64.5 % in the surface and 70.9 % in the subsurface soils. Clay (sandy-clay loam to clay) constituted 35.5 % in the surface and 29.1 % in the subsurface soils. In all of the soil samples collected, clay content was higher in the subsurface than in the surface soils, while the content of sand decreased from the surface to the subsurface soils. This was probably as a result of the movement of clay downward in the profiles and/or due to surface washing during the rainy season.

Soil pH ranged from 4.44 to 7.10 with the mean of 5.51 in the surface and 4.28 to 7.47 with the average of 5.58 in the subsurface soils. The soils were generally, strongly acidic to neutral in both surface and subsurface soils.

Soil organic carbon content ranged from 0.19 to 3.18 mg/kg with an average value of 1.05 mg/kg in the surface and 0.09 to 1.60 mg/kg with the mean value of 0.60 mg/kg in the subsurface soils. With the exception of few samples from four locations, all the rest of the samples had higher contents of organic carbon in the surface than in the subsurface soils. This was attributed mainly to the accumulation of both completely decomposed and partially decomposed organic matter on the surface than in the subsurface soils. The content available P soluble in dilute acid fluoride (Bray-1 P) ranged from 2.1 to 24.5 mg/kg with an average value of 9.03 mg/kg in the surface and 1.09 to 34.30 mg/kg with the mean of 5.44 mg/kg in the subsurface soils. There was no regular trend in the distribution of available P with regard to parent materials, vegetation, or texture.

Total nitrogen ranged from 0.09 to 0.36 mg/kg with the mean value of 0.15 mg/kg in the surface and 0.07 to 0.53 mg/kg with an average of 0.14 mg/kg in the subsurface soils. Generally, total nitrogen was higher in clayey soils than in the sandy soils. This might be as a result of high content of organic matter and clay content in clayey soils than in the sandy soils. This was in line with the study of Rayar and Haruna (1985).

DTPA-extractable metallic micronutrient elements in the soils of Savanna regions North-east Nigeria

Available Cu extractable in DTPA ranged from trace to 0.04 with the mean value of 0.13 mg/kg in the surface and from trace to 1.2 mg/kg with the average of 0.26 mg/kg in the subsurface soils. The content was higher in the subsurface than in the surface soils. This was in line with the report of Tisdale *et al.* (1985). Chude *et al.* (1993), also observed that Cu content increased with depth, which coincided with increase in clay content in most of the profiles examined.

Distribution of available metallic micronutrient elements along with some few soil properties according to parent materials was shown in table 1. Soils developed from basalt had the highest content of Cu in both surface (0.30 mg/kg) and subsurface soils (1.20 mg/kg). Soils formed from Aeolian sand contained the lowest contents of DTPA Cu in both surface (trace) and subsurface soils (0.20 mg/kg). Variation in available Cu with respect to vegetation and texture followed the same trend as that in parent materials. Regardless to soil depth, parent materials, vegetation or soil texture, the soils were adequate in Cu extractable in DTPA, regarding 0.1 mg/kg as critical value as proposed by Lindsay and Norvell (1978). DTPA extractable Cu correlated positively with clay content (r = 0.845**), while negatively correlated with sand (r = - 0.865**), available P (r = - 0.670**) and total nitrogen (r = - 0.324*).

There was no regular trend in the distribution of DTPA extractable Fe with regard to soil depth, parent materials, or vegetation, however, the content was higher in both surface and subsurface of clayey soils than in the sandy soils. This could be attributed to the movement of clay particles down the soil profile. Regardless of all soil factors, 100 % of the samples were sufficient in DTPA Fe when 2.5 mg/kg is considered as the critical value as proposed by Cox and Kamprath (1972). Available Fe correlated positively with total nitrogen (r = 0.700**), but negatively correlated with available P (r = - 0.972**).

Available Mn extractable in DTPA ranged from 3.0 to 19.0 mg/kg with the average of 13.94 mg/kg in the surface and from 4.0 to 18.0 mg/kg with a mean value of 11.23 mg/kg in the subsurface soils (Tables 1-3). Generally, Mn was higher in the surface than in the subsurface soils. Chude *et al.* (1993), also reported that within the profiles, the exchangeable Mn was highest in the topsoil and decreased with depth. Regardless of parent materials (Table 1), vegetation zones (Table 2) and soil texture (Table 3), 100 % of the soil samples collected showed adequate supply of available Mn extractable in DTPA considering 1.0 mg/kg as the critical limit. Lombin (1983), reported that chances of Mn deficiency problem in the savanna zones of Nigeria were remote. Kayode and Agboola (1983), also observed that Mn did not limit the yield of maize in all the soils investigated in Nigeria. DTPA extractable Mn correlated negatively only with available P (r = - 0.863**).

The content of DTPA extractable Zn in the surface soils ranged from 0.2 to 2.0 mg/kg with a mean value of 0.78 mg/kg and in subsurface from 0.2 to 0.8 mg/kg with an average of 0.62 mg/kg. Zinc content was higher in most of the surface than in the subsurface soils, in other samples the content was the same. This showed that Zn distribution was not so much affected by soil depth. Takar (1982), also reported that there was no particular relationship of Zn with soil depth. Taking 0.80 mg/kg as the marginal limit (Lindsay and Norvell, 1978), 80 % of the sandy and 90 % of the clayey soils were deficient in Zn extractable in DTPA. Soils developed on basalt contained the highest content of DTPA Zn in both surface (1.05 mg/kg) and subsurface soils (0.65 mg/kg). Those soils formed from Aeolian sand deposits contained the lowest content of DTPA Zn in both soil depths. Chude *et al.* (1993), also reported that soils formed on basalt and shale contained the highest contents of 0.1 N HCl extractable Zn, while those developed from basement complex had the highest content of DTPA Zn. Extractable Zn from soils of coastal plain sand and Aeolian sand remained relatively low. Zinc extractable in DTPA had a negatively significant correlation with percentage sand (r = - 0.613**). Singh *et al.* (1988), reported that available form of Zn correlated negatively with sand but positively with silt and clay. Zinc extractable in DTPA was unexpectedly not significantly correlated with soil pH. Kwari *et al*. (1999b), also observed that distribution of Zn was not affected by clay content and soil pH. Lombin (1983), earlier also reported that DTPA extractable Zn in Nigerian semi-arid soils is not strongly affected by soil pH.

CONCLUSION AND RECOMMENDATION

Results from the analysis indicated that areas represented by the majority of the soil samples were deficient in Zn extractable in DTPA. Available Cu was also probably deficient in the soils. However, Fe and Mn were found to be sufficient in the soils of the study area regardless of parent materials, vegetation zones or soil texture. Among the parent materials, basalt and alluvium seemed to have higher contents of available micronutrients than any other parent materials. Available micronutrients were generally low in soils developed on Aeolian sand deposits. DTPA extractable micronutrients also showed decreasing trend from the Southern Guinea savanna northward to the Sahel savanna.

Application of mineral fertilizers containing micronutrients to the savanna soil will definitely increase the available status of micronutrients as well as their availability to plants in the study area. Addition of animal manure and crop residues will also enhance and maintain the level of micronutrients in these soils.

Table 1: Status of metallic micronutrient elements and some important soil properties according to parent materials

Soil properties	Soil Depth	**Aeolian**	**Sand**	**Alluvium**		**Basalt**		**Basement**	**complex**	**Sandstone**	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
DTPA-Cu	S	Trace	Trace	Trace-0.4	0.20	Trace-0.4	0.20	Trace-0.4	0.15	Trace-0.4	0.13
(mg/kg)	SS	Trace-0.4	0.20	Trace-0.4	0.20	Trace-1.4	1.20	Trace-0.4	0.18	Trace-0.4	0.13
DTPA-Fe	S	7.00-11.0	8.80	8.00-10.0	9.00	7.00-14.0	10.50	7.00-18.0	11.29	8.00-16.00	10.67
(mg/kg)	SS	6.00-10.0	7.60	8.00-11.0	9.50	10.0-11.0	10.50	7.00-13.0	10.16	7.00-16.00	11.16
DTPA-Mn	S	3.00-14.0	9.00	13.0-16.0	14.50	15.0-19.0	18.50	7.00-13.0	10.16	11.00-18.0	14.60
(mg/kg)	SS	4.00-14.0	8.80	12.0-16.0	14.00	10.0-19.0	18.50	4.00-18.0	13.69	9.00-18.00	14.00
DTPA-Zn	S	Trace-0.5	0.22	0.20-0.50	0.30	0.80-1.30	1.05	0.20-2.00	0.52	0.20-0.50	0.40
(mg/kg)	SS	Trace-0.5	0.22	0.20-0.50	0.35	0.50-0.80	0.65	0.20-0.50	0,29	0.20-0.50	0.30
pH (1:2.5	S	5.08-6.17	5.64	5.17-5.95	5.55	4.66-6.31	5.45	4.44-6.15	5.78	4.65-6.32	5.61
H_2O)	SS	4.61-6.12	5.36	4.94-5.73	5.32	4.94-6.29	5.62	4.28-6.28	5.24	4.71-6.77	5.66
Organic	S	0.21-0.57	0.37	0.70-1.01	0.86	2.16-2.94	2.55	0.19-3.18	1.14	0.53-1.48	1.03
Carbon (mg/kg)	SS	0.16-0.51	0.32	0.35-0.86	0.61	1.30-1.74	1.52	0.09-1.76	0.76	0.38-1.31	0.81
Bray-1 P	S	3.50-23.1	10.64	8.40-34.3	12.60	2.80-3.00	3.15	2.80-18.2	8.32	2.10-24.5	11.83
(mg/kg)	SS	5.10-29.4	15.16	8.40-34.3	10.78	1.40-2.80	2.10	2.10-17.5	7.21	2.80-11.2	6.53
Total	S	0.08-0.14	0.11	0.12-0.36	0.24	0.14-0.25	0.195	0.07-0.36	0.161	0.11-0.25	0.152
Nitrogen (mg/kg)	SS	0.07-0.14	0.096	0.09-0.16	0.125	0.29-0.30	0.30	0.07-0.53	0.165	0.08-0.16	0.11

S= Surface soils (0-20 cm), SS= Sub-surface soils (20-50 cm)

Table 2: Status of metallic Micronutrient Elements and some important Soil properties According to Vegetation Zones

Soil properties	Soil Depth	**Southern G.**	**Savanna**	**Northern G.**	**Savanna**	**Sudan Savanna**		**Sahel Savanna**	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean
DTPA-Cu (mg/kg)	S	Trace-0.40	0.24	Trace-0.40	0.19	Trace-0.40	0.07	Trace	Trace
	SS	Trace-1.20	0.40	Trace-1.20	0.28	Trace-0.40	0.14	Trace-0.40	0.20
DTPA-Fe (mg/kg)	S	9.00-14.00	11.00	7.00-18.00	11.31	7.00-13.00	10.36	7.00-10.00	8.50
	SS	8.00-12.00	9.00	7.00-16.00	9.77	4.00-13.00	9.75	6.00-9.00	7.50
DTPA-Mn	S	4.00-19.00	13.20	10.00-19.00	14.92	5.00-16.00	12.09	3.00-14.00	8.50
(mg/kg)	SS	2.00-18.00	12.20	9.00-19.00	14.15	7.00-16.00	11.36	4.00-14.00	9.00
DTPA-Zn (mg/kg)	S	0.50-1.30	0.72	0.20-2.00	0.52	0.20-0.80	0.34	Trace-0.20	0.10
	SS	0.20-0.80	0.44	0.20-0.80	0.29	0.20-0.50	0.34	Trace-0.20	0.10
pH (1:2.5 H_2O)	S	4.44-5.77	4.93	4.65-6.32	5.62	5.23-7.10	5.65	5.37-6.11	5.74
	SS	4.28-5.78	4.81	4.71-6.77	5.61	4.61-7.47	5.48	5.51-6.12	5.82
Organic Carbon	S	0.92-3.18	2.06	0.19-2.16	1.04	0.21-1.09	0.61	0.21-0.57	0.39
(mg/kg)	SS	0.53-1.76	0.94	0.09-1.74	0.79	Trace-1.01	0.55	0.19-0.41	0.30
Bray-1 P (mg/kg)	S	2.80-18.20	10.78	2.10-24.00	7.08	2.80-23.10	10.36	3.50-16.10	9.80
	SS	2.80-13.30	6.72	2.10-14.00	5.11	2.80-34.30	13.36	13.50-16.80	15.15
Total Nitrogen	S	0.07-0.15	0.13	0.08-0.36	0.18	0.08-0.36	0.15	0.04-0.14	0,14
(mg/kg)	SS	0.08-0.45	0.21	0.07-0.53	0.15	0.07-0.16	0.11	0.11-0.16	0.13

S= Surface soils (0-20 cm), SS= Sub-surface soils (20-50 cm)

Table 3: Status of metallic Micronutrient Elements and some important Soil properties According to Textural Classes

Soil Properties	Soil Depth							
	Surface		**Soils**		**Sub-surface**		**Soils**	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Textural Class	**Loamy sand-**	**Sandy loam**	**Sandy clay loam-**	**Clayey**	**Loamy sand-**	**Sandy loam**	**Sandy clay loam-**	**Clayey**
DTPA-Cu (mg/kg)	Trace-0.40	0.149	Trace-0.40	0.145	Trace-1.20	0.189	Trace-1.20	0.36
DTPA-Fe (mg/kg)	7.00-14.00	10.50	10.00-16.00	11.18	4.00-12.00	9.00	8.00-16.00	11.70
DTPA-Mn (mg/kg)	3.00-19.00	12.42	7.00-19.00	14.27	2.00-17.00	11.71	8.00-19.00	13.77
DTPA-Zn (mg/kg)	0.20-2.00	0.49	0.20-0.80	0.42	0.20-0.80	0.29	0.20-0.80	0.40
pH (1:2.5 H_2O)	4.44-7.10	5.51	4.65-6.32	5.55	4.28-7.47	5.45	4.71-6.29	5.48
Organic Carbon (mg/kg)	0.19-3.18	1.05	0.39-2.16	0.93	0.09-1.76	0.66	Trace-1.74	0.77
Bray-1 P (mg/kg)	2.80-23.10	9.40	2.10-24.50	8.86	2.00-29.40	8.22	1.40-34.30	11.31
Total Nitrogen (mg/kg)	0.07-0.36	0.16	0.11-0.36	0.17	0.07-0.53	0.15	0.08-0.29	0.14

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