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Research Paper

Depth Distribution of Available Micronutrients under Different Land-use Systems

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A survey technique guided field sampling was carried out in land-use options at Abocho Dekina, Kogi State, Nigeria. Three land-use system: Forested, cultivated and fallow areas were located as the study site. At each site a profile pit was dug and soil samples were collected from genetic horizons for laboratory analyses. The obtained results indicated that the soil pH was extremely–slightly acid (4.28-6.99), organic carbon ranged from low to high especially in cultivated land-use systems while the cation exchange capacity was low to medium (2.4-7.2 cmol(+)kg^{-1}). The current status of copper, zinc, iron and manganese varied from 0.34 to 0.61, 0.30 to 0.44, 17.58 to 33.91 and 23.95 to 44.45 $mgkg^{-1}$, respectively. Similarly, the Zn level in all the land-use options was rated low while Cu, Fe, and Mn contents were rated medium to high. The simple linear correlation showed strong positive significant relation between Zn and OC; Fe and clay content whereas negative significant correlation was exhibited in Zn, Cu and clay; Mn and sand fraction. The crops will benefit from supplementary application of these micronutrients for maximum productivity. Fe and Mn values were "high" and above the critical limits for arable crop production in all the horizons across the land-use system. The soils will not require supplementary application of Fe and Mn.

Key words: Abocho, land-use, Micronutrients,soil fertility.

INTRODUCTION

Soil fertility is the ability of soil to supply nutrients that is required by plant in available and suitable form. Soil fertility is determined by the presence or absence of nutrients which is macro and micronutrients. Micronutrients in particular, Fe, Mn, Zn and Cu are known as "Transitional elements" but micronutrients are preferred term. The amount and distribution of micronutrients in profile soils serve as indicators of the sustainable productivity of an agro-system across land use options. Plants require a range of (Fe, Cu, Zn and Mn), as essential for normal growth and development (Mustapha *et al.*, 2010). Thus, they can be toxic when are in excess, but when in deficit supply, deficiency symptoms can appear and growth is reduced. The micronutrients in the soil and their availability to plants are determined by the minerals contained in the original parent material and by the weathering processes that take place over the year. Although, micronutrients are in minute quantities, but have the parallel agronomic importance as macronutrients have (Nazif *et al.*, 2006).The main objective of this study was to assess the depth distribution of available micronutrients under different land use patterns.

MATERIALS AND METHODS

Site location

The study was conducted in the Abocho, Dekina Local

Table 1. Physical properties of soils at Abocho in Dekina L.G.A Kogi State, Nigeria.

Horizon Profile A: Woodlot Cashew	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural class
Ap	0-20	85	3	12	Loamy sand
Bt1	20-86	65	3	32	Sandy clay loam
Bt2	86-120	53	3	44	Sandy clay
Bt3	120-168	55	3	42	Sandy clay
BC	168-200	59	3	28	Sandy clay loam
Mean		63.4	3	31.6	
Profile B: Cultivated					
Ap	0-18	89	3	8	Sand
AB	18-36	85	5	10	Loamy sand
Bt1	36-94	51	1	48	Sandy clay
Bt2	94-160	57	3	40	Sandy clay
Bt3	160-200	45	3	52	Clay
Mean		65.4	3	31.6	
Profile C: Natural fallow					
Ap	0-27	81	7	12	Loamy sand
Bt1	27-73	57	1	42	Sandy clay
Bt2	73-150	51	1	48	Sandy clay
Bt3	150-187	55	3	42	Sandy clay
BC	187-200	51	5	44	
Mean		59	3.4	37.6	

Government, Kogi State, Nigeria located in the Longitude between 06°584.5'- 07°33.3'E and Latitude 06°38.5'-07°85.10'N and has an altitude of 420-408 m above the sea level .It is in the Northern central zone of Nigeria. The geographical terrain of the study area is predominantly flat with low plains and highly forested vegetation. The climate of the study area is divided into two distinct seasons; the wet (March to October), the dry (November to April) and has an annual average rain fall of about 1500 mm per annum, while the temperature is rated hyperthermic. The main crops grown in the area are maize, sorghum, millet, and cassava on the cultivated land, cashew, locust beans for upland and vegetable, rice on the *fadama*. The vegetation of the area is classified under northern guinea savannah. The most species of grass and trees commonly found in the area are Locust bean (*Parkia biglobosa*), neem (*Azadirachta indica*) Baobab (*Adansonia digitata*) and cashew as the major economic crops, with vast farm lands with lots of vegetation reserves and shelter belts.

The study was conducted from November to March 2011-2012 on three land use systems. These were (1) natural fallow site with indigenous plant species and a soil surface covered by a fairly thick layer of residue of leaves and twigs, (2) an adjacent plot with continuous cultivation using conventional methods of farming and (3) a cashew woodlot adjacent to the cultivated field. One representative profile was dug on each land use system and soil samples were collected from the genetic horizons for laboratory analyses. Soil samples were air-dried in the laboratory, ground and sieved through a 2 mm sieve, and the fine earth (< 2 mm) used for laboratory analyses. Particle size distribution was determined by the hydrometer method, using sodium hexametaphosphate (Calgon) as the dispersant (Bouyoucos, 1951). Measurement of soil pH was done in a 1:1 using a glass electrode pH meter, while organic carbon was determined by the wet combustion method by Walkley and Black, the extraction of Ca, Mg, K and Na was made using 1N NH_4OAc (pH 7) solution, Ca^{2+} and Mg^{2+} in solution were read on an atomic absorption spectrophotometer, while K^+ and Na^+ were read on the flame emission photometer. Cation exchange capacity was determined by the NH_4OAc saturation method (Chapman, 1965). The extractable micronutrients: Zn, Cu, Fe, and Mn were extracted with 0.1m HCl Solution (Osiname *et al.,* 1973) and determined on atomic absorption spectrophotometer at appropriate wavelengths. The relationship between various soil properties and micronutrients content was established using simple correlation.

RESULTS AND DISCUSSION

Physical properties of the soil

The data on the physical properties of the soils in the studied areas are presented in (Table 1). The results on particles size analysis indicated that the soils were found to be containing more than 50% mean value of sand. Five different soil texture particles namely; sand, clay, sandy clay, loamy sand and sandy clay loams were recorded irrespective of land use systems. The silt content

Table 2. Chemical properties of the soils at Abocho in Dekina L.G.A Kogi State, Nigeria.

Profile A: Woodlot Cashew	Depth (cm)	pHw	Org. C	TN (%)	Avail. P Mgkg^{1}cmol(+) kg^{-1}	CEC	Ca	Mg	Na	K	ECEC (Soil)	Base Saturation (%)
AP	0-20	6.99	0.69	0.7	5.27	4.8	2.21	0.54	0.09	0.23	5.81	64
Bt1	20-86	5.13	0.20	0.04	4.11	4.0	1.85	0.50	0.10	0.18	4.23	66
Bt2	86-120	4.90	0.12	0.04	3.62	3.6	1.73	0.61	0.11	0.19	5.04	73
Bt3	120-168	4.88	0.10	0.4	3.63	3.2	2.06	0.73	0.10	0.16	5.05	95
BC	168-200	5.00	0.10	0.4	2.99	2.8	1.78	0.54	0.12	0.19	5.43	94
Mean		5.38	0.24	0.32	3.94	3.68	1.93	0.58	0.10	0.19	5.11	78.4
Profile B: Cultivated												
Ap	0-18	6.38	2.68	0.25	13.58	7.2	3.78	1.06	0.08	0.35	5.67	73
AB	18-36	6.78	1.84	0.21	11.88	6.4	3.65	0.92	0.09	0.34	5.80	78
Bt1	36-94	6.75	0.28	0.04	5.86	3.6	1.88	0.52	0.10	0.20	3.90	75
Bt2	94-160	6.27	0.40	0.04	7.88	3.3	1.81	0.62	0.11	0.17	3.51	82
Bt3	160-200	5.34	0.06	0.04	5.15	5.5	1.77	0.60	0.11	0.18	3.86	76
Mean		6.30	1.05	0.12	8.87	5.2	2.58	3.24	0.10	0.25	4.55	76.8
Profile C: Natural fallow												
Ap	0-27	4.35	0.08	0.07	26.51	4.4	2.58	0.75	0.11	0.29	6.53	85
Bt1	27-73	4.28	0.32	0.07	3.96	3.2	1.48	0.53	0.12	0.14	4.27	71
Bt2	73-150	4.45	0.06	0.04	45.56	2.8	1.72	0.64	0.06	0.18	5.89	96
Bt3	150-187	5.75	0.22	0.4	27.83	2.4	1.69	0.68	0.13	0.19	5.89	96
BC	187-200	6.57	1.24	0.4	26.52	3.0	1.70	0.57	0.11	0.18	4.96	85
Mean		5.08	0.38	0.32	26.08	3.16	1.83	0.63	0.11	0.20	5.51	86.6

Org. C = organic carbon, TN = total nitrogen (%), CEC = cation exchange capacity, ECEC= Effective cation exchangeable

was ranged between 1-7%, and clay content ranged 8-52%, across land use systems. Higher percentage of clay content in depth might be due to the eluviation and illuviation process. Similar trend of gradual increase in clay content with depth was observed by Ajiboye *et al.* (2008), in the soils elsewhere in Kogi State.

Chemical properties

The data on chemical properties of soils (Table 2) revealed that the soils were found to be extremely-slightly acid (pH 4.28-6.99), in soils reaction. This might be probably due to the nature of parent material in the study areas. In general, the organic carbon contents soils under different land use systems was ranged low-high (0.06-2.68%), and decreased with depth. The highest concentration of OC in the cultivated land could be due to the prolonged use of agricultural inputs. While, low of OC content in the forested and fallow might be due to the high temperature and sometimes rainfall, which accelerate rate of decomposition of organic matter. The values of total nitrogen (TN) content across land use options vary from 0.04-0.7% with variable values in the all surface soils and sharp decreased with depth. It is rated high, according to Esu, (1991).The results of the total N content showed that the values of non-arable lands were higher than those of the cultivated land.

The difference in this result may be due to the often uptake of N by crop plants in the cultivated land or might assigned due to the fact that both forested and fallow lands have abundant litter materials which not incorporated by plough. The highest content of total N in the areas could be probably due to the clay content of the soils, because clayey soils have double N content of Sandy soils. The available P content in all the profiles under different land use systems varied

Table 3. Distribution of micronutrients (mg kg^{-1}) of soils at Abocho in Dekina L.G.A Kogi State, Nigeria.

Horizon	Depth (cm)	Cu	Zn	Fe	Mn
Profile A: Woodlot Cashew					
Ap	0-20	0.93	0.63	11.50	18.96
Bt1	20-86	0.61	0.43	37.86	52.66
Bt 2	86-120	0.55	0.24	49.72	63.86
Bt 3	120-168	0.69	0.52	36.11	41.73
BC	168-200	0.34	0.18	29.06	37.15
Mean		0.62	0.40	32.85	42.87
Profile B: Cultivated					
Ap	0-18	1.25	0.94	7.99	11.67
AB	18-36	0.72	0.54	11.11	13.04
Bt1	36-94	0.48	0.34	15.93	23,03
Bt2	94-160	0.22	0.18	25.68	39.22
Bt3	160-200	0.36	0.22	27.18	32.77
Mean		0.61	0.44	17.58	23.95
Profile C: Natural fallow					
Ah	0-27	0.47	0.39	8.88	17,14
Bt1	27-73	0.55	0.26	29.40	38.78
Bt2	73-150	0.49	0.43	37,06	52.86
Bt3	150-187	0.21	0.13	52.13	71.06
BC	187-200	0.49	0.31	42.10	42.41
Mean		0.34	0.30	33,91	44.45

widely from 2.99-45.5Mg kg^{-1}.These values fall between low-high, according to Esu (1991).The highest value obtained from all horizons in Fallow land, except with low content of 3.96 Mg kg^{-1},but medium values observed in the Ap and AB Pedons of cultivated land. Consequently, the rganic carbon did not contribute to the variation of available P of soils. The low cation exchange capacity (CEC), values of the all profile soils were observed, except Ap and AB horizons with values of 7.20 cmol (+) kg^{-1} and 11.88 cmol (+) kg^{-1} were obtained in cultivated land. The low of CEC may be due to the dominance of Kaolinite type of clay which has low sorption characteristics compared to Montmorillonite clay type. These results find support from the findings of Mustapha, (2007), in soils elsewhere in northern Savanna of Nigeria. This also in line with values were reported by Fadama land in Kogi State (Fadama II, 2008).The decrease of CEC in all profiles with increase in depth was observed. The exchangeable calcium content ranged between 1.48-3.78 cmol (+) kg^{-1}, irrespective of land use systems. It is rated, according to Esu (1991), as generally low-medium, but medium value obtained in the Ap, AB and Ap pedons in the cultivated and forested land, respectively. The exchangeable Mg and K contents in all profile soils were rated medium-high, except Bt_1 horizon in Fallow land, which rated low (Esu, 1991). These soils could be adequately enriched in these exchangeable bases. Exchangeable Na was low-medium. The higher value was observed in the Fallow land, besides its Bt_1pedon with low content. Thus, both Forested and cultivated had low content of Na.

The effective cation exchangeable capacity (ECEC) had value ranged between 4.23-6.53 cmol (+) kg^{-1} .It is rated, as productive land, Hassan, (2010) reported that any soils has > 4 cmol (+) kg^{-1} ECEC is less productive. The % base saturation ranged from 64-96 in all pedons, indicating higher native productivity of these lands.

Distribution of micronutrients

The copper content in the studied ranged from medium-high (0.21-1.25 mg kg^{-1}), under different land use system (Table 3). The highest value of 1.25 mg kg^{-1} was obtained in the surface soils of cultivated land, could be due to the chelating effect of organic matter. The zn content was very low in all profiles value of 0.98 mg kg^{-1} was found in the surface soils of cultivated land. Considering 0.8 mg kg^{-1} as critical limit, the soils across land use systems showed Zn deficiency. Therefore, it suggests requiring detailed investigation of spatial distribution of Zn in these soils for proper management practices. These results might be attributed due to the high phosphate content of all the soils may reduce the availability of Zn.

The Fe and Mn contents ranged from 7.99-52.13 mg kg^{-1} and 11.67.71 mg kg^{-1} in all the profile soils across land use systems, respectively. Fe and Mn values were high and above the critical limits for arable crop production. This could be due to acidic conditions of the soils in the study areas. The results are expected as Fe/Mn concretions were observed in the entire horizon during sampling and also lead to development of plinthic horizon due to the high contents of Fe and Mn in a redoximorphic environment caused by a large seasonal

Table 4. Correlation between micronutrients with selected soil properties.

Micronutrients	Sand	Salt	Clay	pH	OC	Ca	Mg	K	Na
Cu	0.381	0.024	-0.633*	0.298	0.711	0.558*	0.609*	0.609*	0.585*
Fe	0.602*	-0.242	0.705**	-0.364	-0.465	0.686**	0.422	-0.693**	0.358
Zn	0.412	0.091	-0.663**	0.311	0.714**	0.775**	0.654**	0.684**	-0.705**
Mn	-0.542*	-0.306	0.670*	0.417	-0.548*	0.703**	-0.444	-0.687**	0.327

OC = organic carbon, ** at 1%, * at 5%

variation as well as a result of fluctuations both in monthly rainfall and temperature. Toxicity of these transitional elements is unlikely for now on surface soils but there is possibility in depth.

Correlation matrix between micronutrients and selected soil properties

Copper (Cu) with selected soil properties

Positive non-significant correlation was obtained between Cu and Sand (0.381 (Table 4).The results was in contrary with findings of Chinchmalatpure *et al.*(2000), and Bassirani *et al.*(2011), who reported negative non-significant correlation between Cu and Sand. A significant non-positive correlation between Cu and Silt (0.024) was observed. Similar results were reported by Bassirani *et al.* (2011). The correlation value between Cu and Clay was -0.663*. It showed that there was negative but significant correlation between Cu and Clay. Hence, increasing clay content in soils provides more sites for adsorption of metals thus reducing bio available Cu. These results find support from findings of Ibrahim *et al.*(2011), and Bansal (2004), who reported negative significant correlation between Cu and Clay, but contrary with Nazif *et al.*(2006), who observed positive correlation between them. The results also showed Cu had a positive non-significant with soil pH (0.298). Hence, some soils studies have found little relationship between soil pH and Cu concentration in the soil solution. The Cu was positively non-significant with organic matter (0.711).This could be due to the chelating effect of organic matter. This result contrary with the findings of Yadav (2008), who found negative correlation between Cu and organic matter. The Cu had a positive significant correlation with Ca (0.558*), Mg (0.609*), K (0.609*) and Na (0.585*). These results that as exchangeable base increase, the bioavailability of Cu will be increase.

Iron (Fe) with selected soil properties

A positive but significant correlation of Fe and Sand (0.602*), was observed. Unparalleled observation was made by Nazif *et al.* (2006), elsewhere in Indian, who reported negative significant between Fe and Sand. It showed that Fe had a negative but non-significant correlation with Silt (-0.242), soil pH (-0.364), OC (-0.465) and Mg (-0.422). Parallel results were reported by Yadav (2011) who suggested that the reduced Fe-availability with increasing soil pH might be attributed due to the conversion of Fe^{2+}-Fe^{3+} ions. A negative but non-significant correlation between Fe and OC could be due to the formation of organic complexes between Fe and OC caused by poor soil aeration and thus, reduce bio-available Fe to Ferric ion (Fe^{3+}) which has low solubility in the soil solution. These results suggested that both Soil pH and organic matter at certain soil conditions can decrease bio-available Fe due to the formation of ferric ion. Available Fe^{2+} correlated positively significant with clay (0.705**) and Ca (0.686**), indicating as clay content increase, availability of Fe increase might be due to the adsorption properties of clay materials. A negative but significant correlation was obtained between Fe and K (-0.693**). Fe had a positive non-significant with Na (0.358).

Zinc with selected soil properties

A positive non- significant correlation between Zn with Sand (0.412), Silt (0.091), and Soil pH (0.311) were obtained. Similar observation was made by Bansal (2004), and Patiram *et al.* (2000), who reported positive non- significant correlation between Zn and soil pH. A highly positive significant correlation of Zn and OC (0.714**) was observed. This might be ascribed due to the chelating effect of organic matter. The correlation value obtained between Zn and Clay was -0.663**. It revealed that Zn was negative significant correlation with Clay. This probably due to the high clay content in depths that provide more sites for adsorption of metals thus, reducing the directly bio-available metals in particular Zn. A positive but significant correlation between Zn and exchangeable bases was obtained except Na (-0.705**) with negative significant correlation.

Manganese with selected soil properties

Available Mn had a negative but significant correlation with Sand (-0.542*), OC (-0.548*) and K (-0.687**). A negative significant correlation between Mn and sand was find support from findings of Chinchmalatpure *et al*.(2000) and Nazif *et al*. (2006) who observed negative but non-significant between Mn and Sand. It showed negative significant relationship between Mn and organic carbon. This may be due to the formation of organic matter complexes between OC and Mn. In general plants are unable to absorb Mn^{3+} from organic complexes and thus, the bioavailability of Mn decreases. Additionally, other soil factor like poor aeration and microbial activity can oxidize Mn^{2+} to less available forms (Mn^{3+} or Mn^{4+}). Available Mn showed non-significantly and negatively correlated with Silt (-0.306) and Mg (-0.444), but positive non –significant with Soil pH (0.417) and Na (0.327). The correlation value between Mn and Ca was 0.703**. As Manganese content increase in the soil, thus increasing the directly available Ca.

Conclusion

Based on the obtained results the contents of macro and micro nutrients were sufficient in cultivated land due to balanced agricultural inputs. However, deficiency of Zn is of the major concern among micronutrients particularly in fallow and forested land. These results might be attributed due to the high phosphate content of the soils which may reduce the Zn availability. Besides, soil properties, the land use systems have also a great influence on the micronutrients availability to crop. The crops will benefit from supplementary application of these micronutrients for optimum growth and crop yield across land use systems. The soils will not require supplementary minerals of Fe and Mn.

AUTHORS` DECLARATION

We declare that this study is an original research by our research team and we agree to publish it in the journal.

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