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Status and Distribution of Available Micro-nutrients in Soils of NIFOR Main Station

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Abstract

Status and distribution of available micronutrients in soils of the Nigerian Institute for Oil Palm Research (NIFOR) main station was studied. Two locations; a poorly drained Inland Valley and well drained Upland to cover the extensive variations in soils of the Nigerian Institute for Oil Palm Research (NIFOR) were chosen for the study. Twenty four soil samples were obtained from twelve profile pits dug at the two locations, air dried and sieved with a 2 – mm sieve and analyzed for micronutrients (Zn, Cu, Fe, Cl and Mn) and some selected physico-chemical properties in the laboratory using standard methods. The results indicated that Copper (Cu) and Manganese (Mn) were higher at the poorly drained Inland Valley when compared to the well-drained Upland soils. Mean Copper values at the top and sub soils of the Inland Valley and Upland were 2.85 mg/kg and 2.51 mg/kg and 1.65 mg/kg and 1.37 mg/kg respectively while mean Manganese values at the top and sub soils of the Inland Valley and Upland soils were 3.51 mg/kg and 3.17 mg/kg and 2.84 mg and 2.97 mg/kg respectively. Mean Zinc values of both locations were below the established critical levels, indicating that Zinc was deficient in soils of the Nigerian Institute for Oil Palm Research. There was relatively lack of correlation between the micro nutrients and physico-chemical properties of soils of both locations. Deliberate application of micronutrients in inorganic forms coupled with Composted Empty Fruit Bunches to soils of the Nigerian Institute for Oil Palm Research is suggested as possible ways of improving the micronutrient contents of the soils.

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Introduction

Soils of the Nigerian Institute for Oil Palm Research (NIFOR) main station are developed on Coastal Plain Sand Parent materials. These soils are highly weathered with low nutrient status making fertilizer application inevitable (Osayande *et al.*, 2013). The soils consist of low activity clays (LAC) (NIFOR 1982) with great affinity for phosphorus sorption (Ataga and Omoti, 1978), high exchangeable acidity with a corresponding low exchangeable bases, hence the term acid sands (NIFOR, 1982).

Records have shown that fertilizer application to soils of NIFOR main station have been in the form of macro nutrients such as NPK 15:15:15 or the more robust NPK 12:12:17:2 (Okpamen *et al.*, 2012). The implication is that the micronutrients are often not replenished. For soil fertility maintenance to be sustainable, nutrient inputs to soils must include both macro and micro nutrients (Osemwota *et al.*, 2000; Osayande *et al.*, 2012; Osayande *et al.*, 2014). A practice that involves the replenishment of macro nutrients only tends to increase soil pH. Accordingly, studies on soils of NIFOR main station have shown an increase in soil pH with time (Okpamen *et al.*, 2012), though most commonly reported is the increase in soil pH with depth (Aghimien, Udo and Ataga, 1988; Osayande *et al.*, 2013). Increases in soil pH have been reported to affect the availability of micronutrients (Akporhonor and Agbaire, 2009). As observed by Mckenzie (2003), the availability of the nutrients Manganese (Mn), Iron (Fe), Copper (Cu), Zinc (Zn) and Boron (B) tend to decrease as soil pH increases. The exact mechanisms responsible for reducing availability differ for each nutrient but may include formation of low solubility compounds, greater retention by soil colloids and conversion of soluble forms to ions that plants cannot absorb (Lindsay and Norvell, 1978). In Nigeria, micro nutrient deficiencies are becoming widespread (Chude *et al.*, 1985; Akinrinde *et al.*, 2005; Orhue *et al.*, 2015).

This present study seeks to provide information on the status and distribution of micro nutrients in an inland valley and adjacent upland soils at NIFOR main station. The soils of the NIFOR Inland Valley with moderate management practices according to Osayande (2013) have the potential to support Raphia palms (Raphia *spp*) cultivation due to its constant inundation with water.

Materials and methods

Study area

The Nigerian Institute for Oil Palm Research (NIFOR) is located on Latitude 06°33´N and Longitude 05°37´ with an altitude of 149.4m ASL. It is located in the rain forest zone of Nigeria characterized by rainy season (February / March-November) and dry season (November - February/March. There is a short break in the rains in August, known as 'August break'. Rainfall ranges from 1500 mm to 2135 mm while minimum and maximum temperature ranges are between 21°C to 31°C with a mean annual temperature of 25°C. Four soil series of Acid Sands have been classified at NIFOR main station with their prominent clay type being kaolinite. They are Ahiara, Kulfo, Orlu and Alagba series (NIFOR, 1982). Soils of the Inland Valley are Ahiara series while those of the upland soils are Orlu series.

Soil sampling and Laboratory analysis

Two locations were chosen for the study; the poorly drained Inland Valley adjacent to the river Okhuo and well drained Upland environment. This was done to ensure that the study covered the extensive environmental variations in soils of the Nigerian Institute for Oil Palm Research (NIFOR). Twelve profile pits were sunk in two locations and soil samples were collected from the top and sub soil horizon of the profile pits with the aid of a tubular auger, making a total of twenty four samples. The samples were bagged in polyethylene bags and accurately labelled for transportation to the laboratory. In the laboratory, the soil samples were air-dried and sieved with a 2 mm sieve and analysis on micronutrient status and physico-chemical properties of the soils were done as follows: Micronutrients (Copper, Zinc, Manganese and Iron) were determined by extracting the soil in 1% EDTA, the filtrate was aspirated into an air-acetylene flame of an atomic absorption spectrophotometer and Cu was read at 324.7 nm; Zn was read at 213.9 nm; Mn was read at 279.5 nm; Fe was read at

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248.3 nm while soluble chloride in soil was obtained by silver nitrate titration, Okalebo *et al.*, (1993). Soil pH was determined in a 1:1 soil to water and soil to KCl suspensions using a pH meter (Hendershot *et al.*, 1993). Particle size was determined by the hydrometer method (Gee and Or, 2002). Soil organic carbon was determined by the Walkley-Black method (Nelson and Sommer, 1996).

Table 1: Field morphological descriptions of typical (normal) NIFOR soils

Profile number and soil series	Horizon	Depth (cm)	Colour (moist)	Boundary*	Structure**	Texture***
5 Ahiara Series (normal)	A11	0-11	7,5YR3/4	a,w	1,c,g	Slightly clayey sand (LS)
	A12	11-36	5YR3/4	c,w	1,m,g	Clayey Sand (SL)
	B21	36-70	5YR3/3	d,w	1,m,g	Slightly clayey sand (LS)
	B22	70-104	5YR3/3	d,w	1,m,g	Slightly clayey sand (LS)
	B23	104-136	5YR3/3	d,w	1,m,g	Slightly clayey sand (LS)
	B24	136-174	2,5YR3/6	d,w	1,m,g	Clayey Sand (SL)
	B25	174-200	25YR3/6	d,w	1,m,g	Slightly clayey sand (LS)
10 Kulfo Series (normal)	A11	0-12	10YR3/2	c.w	1,c,g	Slightly clayey sand (LS)
	A12	12-40	7.5YR3/4	d.s	1,m,g	Slightly clayey sand (LS)
	A13	40-78	7.5YR3/4	d,s	1,m,g	Slightly clayey sand (LS)
	B21	78-105	5YR3/4	d,s	1,m,g	Clayey Sand (SL)
	B22	105-135	5YR4/6	d,s	1,m,g	Clayey Sand (SL)
	B23	135-163	5YR5/6	d,s	1,m,g	Clayey Sand (SL)
	B24	163-200	2.5YR5/6	-	2,m,sb	Clayey Sand (SL)
12 Orlu Series (normal)	A11	0-24	7.5YR3/4	c,s	1,m,g	Slightly clayey sand (LS)
	A12	24-55	2.5YR3/4	c,s	2,m,g	Clayey Sand (SL)
	B21t	55-88	2.5YR3/6	c,s	2,m,sb	Very clayey Sand (SCIL)
	B22t	88-126	2.5YR3/6	d,s	2,m,sb	Very clayey Sand (SCIL)
	B24t	126-154	2.5YR3/6	d,s	2,m,sb	Very clayey Sand (SCIL)
	B24t	154-200	2.5YR3/6	-	2,m,sb	Very clayey Sand (SCIL)
6 Alagba Series (normal)	A11	0-7	7.5YR3/4	c,s	1,m,g	Slightly clayey sand (LS)
	A12	7-21	5YR3/4	d,s	2,m,g	Clayey Sand (SL)
	B21t	21-40	2.5YR4/4	d,s	2,m,sb	Very clayey Sand (SCIL)
	B22t	40-67	2,5YR3/6	d,s	2,m,sb	Very clayey Sand (SCIL)
	B23t	67-105	2,5YR3/6	d,s	2,m,sb	Sandy clay (SCl)
	B24t	105-136	2,5YR3/6	d,s	1,c,sb	Sandy clay (SCl)
	B25t	136-200	2,5YR3/6	-	1,c,sb	Sandy clay (SCl)

*a = abrupt, w = wavy, c = clear, d = diffuse, s = smooth
**1 = weak, 2 = Moderate, c = coarse, m = medium, g = granular, sb = subangular blocky
*** LS = Loamy sand, SL = Sandy loam, SCIL = Sandy clay loam, SCl = Sandy clay
Source: NIFOR, 1982.

Data analysis

Data obtained from the laboratory were subjected to One- way analysis of variance (ANOVA) and the Least Significance Difference (LSD) at 5% level of probability was used to separate the means of both the micro nutrients and the selected physico-chemical properties.

Results and Discussion

Morphological description of NIFOR soils

The morphological descriptions of soils of NIFOR main station are shown in Table 1. NIFOR soils being acid sands are similar in physical characteristics. The structures are either weak or strong while the texture on examination between the thumb and forefinger range from slightly clayey sand to clayey sand in the four soil series. The boundaries are typical of tropical soils in being abrupt, wavy or diffuse. The clear and smooth boundaries observed in some of the soils probably revealed the highly weathered nature of the soils.

Physical and chemical properties of NIFOR soils

Some physical and chemical properties of NIFOR soils are indicated in Table 2. Soil pH (H_2O) indicated a slight acidity in soils of the Inland valley with mean soil pH of 5.63 and 5.70 at the top and sub soils of the NIFOR Inland Valley. Soil pH in (KCl) was lower than the values determined in water. ΔpH indicated a net negative charge in the soils exchange complex of soils of both locations (Table 2). This is consistent with the findings of Jailson *et al.*, (2014). According to Jailson *et al.*, (2014), negative values of ΔpH indicate the predominance of negative electric charges in soils exchange complex. Upland soils had moderate soil acidity with mean soil pH (H_2O) of 6.13 and 6.26 at the top and sub soils (Table 2). Soil pH (KCl) at the top and sub soils was lower than the values determined in water in both locations. Soil pH (H_2O) and soil pH (KCl) were lower in soils of the Inland Valley when compared with upland soils. This could be due to water submergence which increases the rate of weathering and leaching of basic components in soils. Organic carbon was higher at the top soil of soils of the Inland valley when compared to upland soils but increased with increasing soil depth, a phenomenon referred to as lithological discontinuity by Aghimien *et al.*, (1988) as cited by Osayande *et al.*, (2013). In Upland soils, Organic carbon decreased with increasing soil depth and was lower than the critical level of between 20 - 30 g/kg in soils as reported by Enwezor *et al.*, (1989).

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Table 2: Some physical and chemical properties of soils supporting Raphia palms at NIFOR main station

Location/ Depth (cm)	pH (H_2O)	pH (KCl)	ΔpH	Organic Carbon (g/kg)	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)	ECEC (cmol/kg)
Inland Valley								
0-15	5.63	4.96	-0.73	13.30	947.50	19.30	33.20	2.18
90-120	5.70	4.70	-0.10	16.30	946.70	23.70	29.70	2.19
LSD	Ns	Ns	0.40	Ns	Ns	Ns	Ns	Ns
Upland								
0-15	6.13	5.25	-0.88	7.83	942.50	20.70	36.80	1.99
90-120	6.26	5.32	-0.95	5.27	910.00	23.20	66.80	3.29
LSD	Ns	Ns	Ns	Ns	17.79	Ns	19.06	0.25

Table 3: Concentration of Micro Nutrients (mg/kg) soils supporting Raphia palms at NIFOR

Depth (cm)	Zn	Cu	Fe	Cl	Mn
Inland valley					
0-15	2.50	2.85	1.16	663.00	3.51
90-120	1.83	2.51	1.42	308.00	3.17
LSD (0.05)	Ns	Ns	Ns	205.40	Ns
Upland					
0-15	2.26	1.65	2.41	450.00	2.84
90-120	1.75	1.37	2.97	379.00	2.97
LSD (0.05)	Ns	Ns	Ns	ns	Ns

ns = non significant

Micro-nutrient status of soils of NIFOR main station

The available micro nutrient status of soils of NIFOR main station is shown in Table 3. At NIFOR Inland Valley, Zinc, Copper, Manganese and Chloride decreased with increased soil depth while Iron increased with increased soil depth. In comparison with the well-drained Upland soils, Zinc, Copper and Chloride had the same trend as the poorly drained Inland Valley soils which suggests that occasional water submergence of soils of the NIFOR Inland Valley did not influence the trend of these micro nutrients in soils of NIFOR main station. Comparatively, Iron and Manganese of Upland soils had the same trend as Iron of soils of the Inland Valley of increasing with increasing soil depth Table 3). Zinc values at the top and sub soils of both locations were below the critical level of 3.0 mg/kg reported by Pam (1990). The low Zinc contents of soils of NIFOR main station may be attributed to the tendency of Zinc to be adsorbed on the clay-sized particles as earlier reported by Alloway (2008). This is also consistent with the findings of Orhue *et al.*, (2015) who reported a low Zinc status of the Basement Complex soils of Edo state. Extractable Cu at the top and sub soils of both locations fell within reported critical levels of 1.0 mg/kg – 3.0 mg/kg as reported by Deb and Sakal (2002). This was however not consistent with earlier findings by Sillanpaa (1982) and later Orhue *et al.*, (2015) who reported Cu deficiencies in the top soils in his global study of soil micronutrients and top soils of basement Complex soils of Edo state respectively. The extractable Cu contents were higher at the Inland Valley than at the Upland soils. Water submergence may have influenced the extractable Cu content of soils of the Inland Valley. Osayande (2013) observed that the NIFOR Inland Valley had higher contents of weatherable minerals than the adjacent Upland soils. This was attributed to the continuous transportation of new materials by water at the NIFOR Inland Valley. This assertion is buttressed by the fact that Cu content of soils is influenced by the soils parent materials as observed by Olowolafe, Owonubi and Omueti, (2012).

Table 4: Correlation coefficient (r) between selected physico-chemical properties and micronutrients of Inland valley soils of NIFOR

	Zn	Cu	Fe	Cl	Mn
Soil pH	0.209	0.285	-0.116	-0.164	0.325
Organic carbon	0.383	-0.266	-0.405	0.046	-0.314
Total N	0.566	-0.535	0.267	0.268	-0.314
Available P	0.494	-0.211	-0.343	0.153	-0.268
K	0.108	-0.255	-0.146	0.059	-0.046
Ca	0.139	-0.410	-0.301	0.255	0.117
Mg	-0.066	-0.147	0.558	-0.093	0.061
S	0.009	-0.526	0.281	-0.041	-0.546
ECEC	0.183	-0.013	-0.144	0.355	0.253
Sand	0.389	-0.601*	-0.043	0.053	-0.423
Silt	0.130	-0.319	0.040	-0.562	-0.478
Clay	-0.282	0.574	0.012	0.226	0.523

* Correlation significant at 0.05 level

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Table 5: Correlation coefficient (r) between selected physico-chemical properties and micronutrients of Upland soils of NIFOR

	Zn	Cu	Fe	Cl	Mn
Soil pH	-0.466	-0.347	0.656*	-0.451	-0.359
Organic carbon	0.312	0.084	-0.411	0.053	-0.166
Total N	0.354	0.115	-0.462	0.140	-0.106
Available P	0.047	-0.238	0.154	-0.439	0.005
K	0.525	-0.189	0.126	0.071	-0.358
Ca	-0.406	-0.037	0.570	-0.349	0.076
Mg	-0.005	-0.242	0.389	-0.056	0.071
S	0.284	-0.258	0.008	0.083	-0.355
ECEC	-0.335	-0.162	0.592*	-0.254	0.039
Sand	0.245	0.305	-0.408	0.251	0.166
Silt	0.035	-0.297	0.101	0.090	-0.083
Clay	-0.278	-0.252	0.419	-0.301	-0.159

* Correlation significant at 0.05 level

Manganese had the same trend as Copper in both locations in being higher at the Inland Valley than at the Upland. Mean Mn values were above the critical level of 1.0 – 4.0 mg/kg Sims and Johnson, (1991) at the top and sub soils of both locations. This means that soils of NIFOR main station are sufficient in Manganese. This is consistent with the findings of Osemwota *et al.*, (2000) who reported that some Ultisols of Edo state appeared to be adequately supplied with Manganese. Iron content of the top and sub soils of the NIFOR Inland Valley was below the critical level of 2.5 - 5.8 mg/kg as observed by Deb and Sakal (2002). The sub soils of Upland soils with a mean of 2.97 mg/kg fell within the critical level of 2.5 -5.8 mg/kg Iron. This is consistent with earlier findings by Orhue *et al.*, (2015) who reported that the soils of the basement complex in derived savanna of Edo state were rich in iron. Mean chloride content was higher at the top soil of the Inland Valley than at the top soil of Upland soils. Though chloride is not normally toxic in soil, even in excess amounts, except when excess amounts of sodium or sodic ions are present (Dang *et al.*, 2006). There is however little or no information on the chloride content of Nigerian soils (Osayande *et al.*, 2012). The relationship between the micronutrients and soils physicochemical properties of both locations is depicted in Tables 4 and 5. At the Inland Valley, Cu was only negatively significantly correlated with sand with r = -0.601, $P < 0.05$) (Table 4) while in Upland soils, Fe was positively significantly correlated with soil pH and ECEC with (r = 0.656, $P < 0.05$) and (r = 0.592, $P < 0.05$) respectively (Table 5). This low correlation between micronutrients and soils physiochemical properties were also observed by Akporhonor and Agbaire (2009).

Conclusion

This study has revealed that micro nutrients deficiencies with respect to Copper and Zinc exists in soils of the Nigerian Institute for Oil Palm Research main station. The contents of Copper and Manganese were higher at the poorly drained Inland Valley than in the Upland soils. The low correlation of micronutrients with physico-chemical properties of soils of NIFOR main station indicated an urgent need to manage the soils organic matter of NIFOR soils that are declining at an accelerated rate. There is also an urgent need to deliberately apply micronutrients to soils of the Nigerian Institute for Oil Palm Research (NIFOR) main station.

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