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Depth-wise Distribution of Micronutrient Cations in Charnockitic Soils

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Abstract: *Micronutrients are essential for good crop performance. This study was to determine the status and distribution of extractable micronutrient cations in profile soils developed on charnockite at Ado, Ijan, Ijesa-Isu, Ikere, Ire and Osin-Itapa, in Ekiti State, Nigeria. The soils were loamy sand to sand texture at the surface horizons with sandy loam to sandy clay loam sub-surface horizons. The clay content increases proportionately with depth confirming the presence of argillic Bt-horizons in charnockitic soils. Soil pH ranged from 5.6 to 7.5. Total N and available P were critically low. The extractable Mn range was 0.01 to 2.72 mg kg*$^{-1}$ *in the soils with the Ap-horizons having the highest contents. The extractable Cu ranged from 0.04 to 12.96 mg kg*$^{-1}$ *and higher in most of the subsurface soils than the surface soils. The extractable Fe was generally high in the Ap-horizons of the soils, ranging from 0.57 to 1163.90 mg kg*$^{-1}$*. Extractable Zn was critically low in the soils having the highest value of 0.31 mg kg*$^{-1}$*. Generally, the micronutrient cations follows an irregular distribution pattern; the extractable Fe and Cu were adequately available but the extractable Mg and Zn were critically deficient in charnockitic soils.*

Keywords: *Charnockite, Distribution, Extractants, Horizons, Micronutrients.*

I. Introduction

Micronutrients are the nutrient elements demanded by plants in a very small but effective quantities. They are also known as trace elements which are as important to plant growth as the level of macronutrients in the soil. Micronutrients content of soils depends upon the soil types, parent material, soil pH, organic matter, clay content, amount of exchangeable bases and phosphate [1]. The availability of micronutrients, especially Zinc (Zn), Copper (Cu), Manganese (Mn) and Iron (Fe) is important for the optimum crop production. Micronutrients were first recognized as limiting factor in crop production in Florida, United States of America during the late 1920s [2]. Earliest micronutrient deficiencies reported in Africa [3], showed that within West Africa, the deficiencies of Fe and Mn occurred in Cote D'Ivoire and Gambia. This was in addition to the more widespread deficiencies of Cu and Zn in many coarse textured, acid soils in Africa and in Nigeria in particular [4, 3]. However, [5], reported that acidic West African soils contain very high amounts of Fe and Mn, with their deficiencies more likely on calcareous or alkaline soils. In their reviewed of few available works on available Fe distribution in Nigerian soils, [6] reported that the Nigerian soils were rich in available Fe content [7, 8, 9]. Most micronutrients are associated with enzymatic activities of plants.

Charnockitic soils are soils developed on charnockite, a rock defines by [10] as a rock with composition of granitic containing orthopyroxene, the pyroxene present is hypersthene, [(Mg, Fe)$_2$ Si$_2$O$_6$] associated or not with biotite, sometimes with amphibole or garnet, opaque minerals (metallic oxides) to which are added leucocratic minerals of the granite, quartz, plagioclase, and potassic feldspar. In addition, [11] also reported the mineral constitution of charnockite rocks to include quartz, perthitic alkaline feldspar, plagioclase feldspars, very weakly pleochroic orthopyroxene, microcline, olivine, hornblende, biotite and accessory zircon, apatite and Fe oxide. Charnockites are found in every continent, but are limited to deep, high grade terraces making them unfamiliar in many regions. Southern India may well provide the world's best and accessible region for the study of charnockites [12]. Africa has about sixty-three citations, which therefore include Ekiti State, Nigeria [13]. Six of such areas where charnockites were found in Ekiti State namely; Ado, Ikere, Ijan, Ijesa-Isu, Ire and Osin-Itapa were chosen for this study.

There is little or no quantitative data about the micronutrient status and distribution in Nigeria, in general, and in the soils developed on charnockite in particular. Most of the soil fertility researches in Nigeria were focused on nitrogen, phosphorus and potassium [14, 15, 16, 17]. In Nigeria today, various insurgences has brought about decline in the food production. The need to meet up with the food demand of the ever increasing population has brought about the need to harness the fertility of the available arable soils particularly in the Southwestern parts, that were hitherto under cultivated or neglected. In order to achieve Nigeria's goal of food sufficiency through the Agricultural Transformation Agenda (ATA), a proper knowledge on the physical and chemical properties of charnockitic soils, especially of some neglected, but important, micronutrients becomes essential. Hence, the necessity to ascertain the extractable contents and profile distribution of the selected micronutrient cations in soils developed on charnockite in six cited areas in Ekiti State in order to suggest and enhance cultural practices and soil amendments to improve the crop yield in the study area.

II. Materials And Methods

The soils studied were collected from profiles dug at six locations: Ado, Ikere, Ijan, Ijesa-Isu, Ire and Osin-Itapa, where charnockite are found in Ekiti State (South Western Nigeria) located between latitude 7^o 40' N and 5^o 15' E. The study area is in an agro-ecological zone having mean annual total rainfall of 1367mm with mean annual temperature of 25 ^oC. The vegetation at Ado Ijan, and Ikere locations are dry forest while other locations are derived savannah, and agriculture is the main land use. The profiles were described by [18] and the soils classified as Alfisols. The soil samples collected at various horizons were air dried, crushed and sieved through 2 mm plastic sieve and kept in plastic bags prior chemical analysis. The pH of the soils were determined in water at 1:1 soil:water ratio. The wet combination Walkley-Black method was employed in the determination of organic carbon and total nitrogen analyzed by the modified micro- kjeldhal digestion procedure while available phosphorus were extracted by Bray P1 method as described by [19]. The mechanical properties of the soils were determined by the hydrometer method. Free oxides of Fe was extracted with dithionite citrate mixture buffered with Na bicarbonate (DCB) [20].

Five different extractants were employed for the extraction of the micronutrient cations (Cu, Fe, Mn, and Zn); these extractants were: Neutral Normal NH_4OAc , NH_4OAc pH 4.8, 0.1 M HCl, 0.05 M HCl + 0.025 M H_2SO_4 , 0.05 M EDTA + 0.1 M $(NH_4)_2CO_3$. 5 g of each prepared soil samples were weighed into four 50 ml and a 100 ml extraction vessels. 25 ml of each extractants were added to the 50 ml extraction vessels except the 0.05 M EDTA + 0.1 M $(NH_4)_2CO_3$ extractant in which 50 ml of it was added to each of the six-100 ml extraction vessels. The vessels were shaken for 5-minutes on a rotary shaker at a minimum of 180 oscillations per minute except for soils treated with 0.1 M HCl which were shaken for 30-minutes at the same oscillation. Filtrate was filtered immediately using Whatman filter paper and the micronutrient cations determined using atomic absorption spectrophotometer. Data collected after the laboratory analyses were subjected to Analysis of Variance using Generalized Linear Model and means were separated by Duncan's Multiple Range Test. Different letters over bars in figures indicate significant differences between groups. Pearson Correlation was used to determine relationship between extractable micronutrient cations and some soil properties.

III. Results And Discussion

3.1. Some properties of the soils developed on charnockite

Some relevant soil properties are presented in Table 1. The pH of the soils ranged from 5.6 to 7.5 indicating moderately acidic to slightly alkaline reactions in the soils. Ado, Ijesa-Isu, Ikere, and Ire soils were acidic except for the Ap-horizon of Ikere, having neutral soil reaction (pH 7.0). Other locations were found to be slightly alkaline, though the Bt_1 horizon of Osin-Itapa was found to be very slightly acidic (pH 6.9). The slightly above neutral pH (> 7.0) observed on soils of profile Ijan, and Itapa-Osin might be due to the liming effect of bush burning. For profiles of Ire, Ado, Ikere and Ijesa-Isu, the acidic pH might be due to the effect of intense cultivation, erosion and leaching of nutrients down the profile. The pH of most of the soils decreased irregularly with depth. These decrease pH values with profile depth could be due to the effect of nutrient biocycling [21]. The pH values indicated that charnockitic soils would give an optimum yield for nearly all crops if all other environmental conditions are favorable. The clay content increases proportionately with depth validating the presence of argillic Bt-horizons in charnockitic soils. The high clay content may be as a result of alluvial parent material as well as the underlying geology, this support the findings of [18]. The silt content decreases down the pedons except at Osin-Itapa where it increases with depth. The total nitrogen (N) and available phosphorus (P) values are critically low [22] in all the soils, as most nitrogen may have been volatilized due to bush burning and most phosphorus fixed organically or by the free iron oxides. These indicates serious N and P deficiencies, as the studied area is a transitional ecological zone supporting the findings of [23] and [24] that the soils of the derived savanna and guinea savannah zones are characterized with N and P deficiencies. All the soils followed the general trend of having the highest organic carbon content at the Ap-horizons although low, and decreases down the profile ranging from 0.99 to 3.91%. The high surface values is an indication of continuous deposition of organic materials from previous cultivations. The generally low organic carbon content could be as a result of high rate of mineralization due to the humid climate, intense cultivation and seasonal burning that characterized the derived Savanna belt [25]. The higher value of free iron oxides in the soils is probably due to the presence of hypersthenes in charnockite rocks.

3.2. Profile distribution of the micronutrient cations in the soils using five extractants

The profile distribution of extractable micronutrients of the studied soils using the extractants are contained in Table 2a – 2c.

Manganese: The amount of extractable Mn ranged from 0.01 to 2.72 mg kg^{-1} with NH_4OAc pH 4.8 having the least detectable value in the Bt_2-horizon at Ikere and 0.1 M HCl having the highest in the Ap-horizon at Ijan. Manganese was below the critical level, 3.0 [24, 26, 27] in the soils indicating deficiency. This supported the findings of [28] that Mn deficiencies are more common in sandy soils having pH above 6.5 and soils high in available Fe. The continuous mineralization of the available organic materials by microbes that changes the available form (Monogamous form, Mn^{2+}) to less available forms (Manganic forms: Mn^{3+}, Mn^{4+}, Mn^{7+}) might contribute to the deficiency of extractable Mn [29] in the studied charnockitic soils. This suggest that a good and sustainable means should be employed in managing the soil health for an optimum nutrient availability. Whereas, [18] reported DTPA-extractable Mn for the Ap-horizons of charnockitic soils to exceed the critical level of 3.0 to 5.0 mg kg^{-1} suggested by [30]. Manganese distribution gradually decreases down the depth in most of the profiles which could be attributed to Mn retention in the organic rather than inorganic colloids and greater susceptibility to leaching losses. Though, some profiles does not followed a particular pattern.
Iron: The values of extractable Fe was generally high in the soils, ranging from 0.57 to 1163.90 mg kg^{1} with Osin-Itapa having the least value and the highest value at Ijan respectively. The extractable Fe decreases from the Ap-horizons to the immediate underlying Bt-horizons in all the profiles except at Ikere with all the extractants, this may be due to natural variation in the soils. The higher levels in the Ap-horizon are similar to results obtained by [31] in soils developed on older granites in Nigeria. The higher Fe content in the soils was contrary to the findings of [28] that Fe availability is higher at pH below 5.0 while the abundance of Fe in the studied soils may be due to hypersthenes present in charnockite rocks. Thus, the soils were sufficient in available Fe and it confirmed the conclusion of [6] in their review work.
Copper: The values of extractable Cu ranged from the least detectable value 0.04 to 12.96 mg kg^{-1} with 0.05 M HCl + 0.025 M H_2SO_4 extractant having the highest values. These values indicates that Cu is adequately distributed in the soils. Solubility of Cu^{2+} is soil pH dependent and decreases 100-fold for each unit increase in pH and vice versa [32, 28]. Moreover, [32] also stated that increases in soil pH above 6.0 induces hydrolysis of hydrated Cu which can lead to a stronger Cu adsorption by the clay minerals and organic matter. The Cu content was generally high in the subsurface horizons than in the surface horizons, contrary to the report by [18] that DTPA-extractable Cu were higher in the surface horizons of Ado, Ikere and Ire but in the subsoil of other pedons. This was in support of the findings of [33] that sub-surface horizons has higher Cu content than the surface horizons. It was also similar to the report of [34] that Cu increased significantly with depth in his study of fadama soils in Bauchi, Nigeria. There is a tendency for downward movement and accumulation of Cu in the lower horizons, although the distribution varied without a particular pattern in the profiles. Tiller [35] suggested the high amount of Cu in agrarian soils studied to be due to $CuSO_4$ accumulation through fungicidal spray on cocoa grown on the land.
Zinc: The profile distribution of the extractable Zn was generally low in the soils with 0.05 M EDTA + 0.1 M $(NH_4)_2CO_3$ having the highest value (0.31 mg kg^{-1}) and does not follow a particular pattern. The extractable Zn is critically low. This is in line with the findings of [36], that the charnockitic soils of Ekiti State Nigeria were low in Zn and available P. It also support the report of [37] that the soil test level is always or often indicative of a need for Zn application. The unavailability of Zn is due to near neutrality condition of the soils reducing the Zn solubility [38, 28]. This supported the findings of [4] that Zn deficiency is common than those of Fe and Mn in the soils of Africa and Nigeria in particular.

3.3. Mean values of the micronutrient cations across the locations

The mean values of the extractable content of the micronutrient cations across all the locations are presented with Figure 1-4. The result from the study showed that charnockitic soils in Ijan has the highest mean values of 0.90 and 426.75 mg kg^{-1} for the extractable Mn and Fe respectively (Fig. 1 and 2) and were significantly different from the mean values obtained for these extractable cations at the other locations. This might be ascribed to the location and varying nature of the parent materials from which the soils were formed. The mean values across the locations showed that the extractable Cu and Zn contents on the other hand were not significantly different from one location to the other. Although Ijesa-Isu showed the highest mean value of 3.72 mg kg^{-1} for extractable Cu (Fig. 3) but the least mean values of 0.12 and 40.18 mg kg^{-1} for Mn and Fe respectively (Fig. 1 and 2) when compared with the other locations. The result also shown extractable Zn is the most deficient micronutrient cation in the soils developed on charnockite at all the locations studied.

3.4. Relationships of the selected micronutrient cations and some soil properties

The extractable Fe and Mn significantly correlated with the organic carbon at $P \leq 0.05$ and 0.01 respectively (Table 3). This shows that these micronutrient cations have strong affinity for organic carbon at the surface level than in the subsurface horizons. Similar report was obtained by [4] in basaltic soils of the Nigerian savannah. The results in this study suggested that percent organic carbon was an important soil property for the retention of Mn and Fe in charnockitic soils and their availability will be influenced by farming practices that would deplete the soil organic matter. The clay content was also significantly correlated but negatively with Fe at P ≤ 0.01. This implies that the availability of Fe in soils developed on charnockite is a function of clay content. There were no significant relationship between the selected soil properties and the extractable Cu, and Zn. This is in agreement with [39], who found no significant relationship between extractable Cu and either soil pH or organic carbon. This may be due to the low clay content in the studied soils as a result of continuous illuviation activities. This supported the findings of [34] that available Zn and Cu are most abundant where the clay content is high.

Table 1. Some properties of soils developed on Charnockite in Ekiti State

Horizon	Depth (cm)	pH (H_2O)	Total N (g kg^{-1})	Avail. P (mg kg^{-1})	Org. Carbon (%)	Fe_2O_3 (g kg^{-1})	Clay (g kg^{-1})
				ADO			
Ap	0 - 11	6.3	0.21	0.22	3.75	2208.9	77.6
Bt_1	12 – 21	5.9	0.10	0.10	2.99	1044.3	157.6
Bt_2	22 – 61	6.1	0.04	0.11	1.67	529.0	297.6
Bt_3	62 – 118	5.7	0.04	0.15	1.47	341.3	327.6
C	119 - 150	5.7	0.06	0.31	0.99	1903.3	337.6
				IJESA-ISU			
Ap	0 – 20	6.3	0.07	0.58	2.59	117.2	77.6
Bt_1	21 – 32	6.2	0.06	0.30	2.27	88.2	127.6
Bt_2	33 – 110	6.0	0.04	0.50	2.19	69.6	187.6
C	111 - 150	6.0	0.04	0.11	1.15	54.8	217.6
				IJAN			
Ap	0 – 20	7.5	0.08	1.36	2.31	3375.3	57.6
Bt_1	21 – 35	7.3	0.07	0.57	2.19	1953.7	97.6
Bt_2	36 – 60	7.3	0.05	2.55	1.83	2535.2	127.6
Bt_3	61 – 90	7.4	0.04	0.34	1.79	537.7	187.6
C	91 - 120	7.4	0.13	0.15	1.63	877.0	187.6
				IRE			
Ap	0 – 20	5.6	0.05	1.11	3.39	2184.8	97.6
Bt_1	21 – 43	5.6	0.04	0.92	2.91	932.1	167.6
Bt_2	44 – 70	5.7	0.06	0.09	2.07	162.7	167.6
C	71 – 120	5.7	0.06	0.03	1.66	105.7	217.6
				OSIN-ITAPA			
Ap	0 – 23	7.3	0.11	0.50	3.91	1405.1	87.6
Bt_1	24 – 50	6.9	0.06	0.25	2.27	1109.0	137.6
Bt_2	51 – 80	7.1	0.07	0.13	2.11	554.5	207.6
C	81 - 130	7.1	0.04	0.05	1.83	141.8	217.6
				IKERE			
Ap	0 – 23	7.0	0.04	0.27	2.91	288.0	67.6
Bt_1	24 – 64	6.8	0.05	0.20	1.67	891.2	117.6
Bt_2	65 – 92	6.4	0.04	0.18	1.19	196.9	187.6
C	93 – 140	6.1	0.05	0.15	1.15	172.0	227.6

Table 2a. Micronutrient status of soils developed on Charnockite in Ekiti State

Horizon	Depth (cm)	0.05 M HCl + 0.025 M H_2SO_4				0.05 M EDTA + 0.1 M $(NH_4)_2CO_3$			
		Mn	Fe	Cu	Zn	Mn	Fe	Cu	Zn
		---------------- mg kg^{-1} ----------------				---------------- mg kg^{-1} ----------------			
					ADO				
Ap	0 - 11	1.40	551.62	3.87	ND	1.91	533.60	4.77	ND
Bt_1	12 – 21	1.01	478.90	2.51	ND	0.68	165.40	3.13	0.22
Bt_2	22 – 61	0.40	193.40	6.62	ND	0.35	185.60	4.27	ND
Bt_3	62 – 118	0.28	128.60	3.53	0.53	0.29	80.50	3.37	ND
C	119 - 150	0.80	626.30	5.71	ND	1.27	531.20	8.75	0.03
				IJAN					
Ap	0 – 20	2.20	1150.20	2.67	ND	1.43	567.80	7.04	0.15
Bt_1	21 – 35	1.45	736.20	4.03	ND	0.60	280.30	3.62	0.28
Bt_2	36 – 60	1.23	1040.30	3.64	ND	2.27	1048.60	7.66	0.05
Bt_3	61 – 90	0.24	240.60	4.06	ND	0.10	30.90	3.63	0.03
C	91 - 120	0.31	283.10	4.03	0.06	0.31	90.60	1.73	0.27
				IJESA-ISU					
Ap	0 – 20	0.26	118.90	12.96	ND	0.27	97.90	4.64	ND
Bt_1	21 – 32	0.11	37.40	7.02	0.03	0.03	39.40	3.08	ND
Bt_2	33 – 110	0.05	31.00	6.77	ND	0.11	28.90	3.11	ND
C	111 - 150	0.16	58.28	9.28	0.14	0.06	23.70	4.14	0.16
				IKERE					
Ap	0 – 23	0.11	129.50	4.35	0.08	0.13	21.90	12.17	0.31
Bt_1	24 – 64	0.69	371.60	6.23	ND	0.51	258.90	4.81	0.26
Bt_2	65 – 92	0.07	130.90	6.37	0.05	0.27	129.50	2.07	0.01
C	93 – 140	0.16	98.90	7.09	0.15	0.22	120.20	3.85	0.31
				IRE					
Ap	0 – 20	1.39	706.10	4.03	0.11	1.35	674.20	10.83	0.17
Bt_1	21 – 43	0.77	355.90	7.50	ND	0.58	299.50	4.14	ND
Bt_2	44 – 70	0.20	82.90	1.27	0.03	0.87	374.70	3.57	0.07
C	71 – 120	0.15	47.20	4.18	ND	0.10	83.80	2.68	0.02
				OSIN-ITAPA					
Ap	0 – 23	1.44	504.50	3.96	0.13	0.97	443.70	3.43	0.11
Bt_1	24 – 50	0.99	454.50	4.66	ND	0.26	98.00	12.88	0.15
Bt_2	51 – 80	0.57	299.50	2.16	0.18	0.57	260.60	5.84	0.01
C	81 - 130	0.04	100.02	10.61	0.13	0.15	24.00	3.77	0.24

† ND: Not detected

Table 2b. Micronutrient status of soils developed on Charnockite in Ekiti State

Horizon	Depth (cm)	0.1 M HCl				NH_4OAc pH 4.8			
		Mn	Fe	Cu	Zn	Mn	Fe	Cu	Zn
		mg kg^{-1}				mg kg^{-1}			
					ADO				
Ap	0 - 11	1.81	761.70	2.32	0.08	0.64	273.90	ND	0.08
Bt_1	12 – 21	0.80	360.10	2.55	ND	0.34	145.80	2.25	ND
Bt_2	22 – 61	0.40	182.40	0.51	ND	0.27	139.80	1.70	ND
Bt_3	62 – 118	0.28	117.70	2.72	0.08	0.17	35.00	1.44	0.08
C	119 - 150	1.45	656.30	2.71	0.05	0.79	352.10	ND	0.05
					IJAN				
Ap	0 – 20	2.72	1163.90	2.07	ND	0.94	391.80	4.54	0.18
Bt_1	21 – 35	1.52	673.70	0.98	ND	0.45	181.30	ND	ND
Bt_2	36 – 60	2.15	874.20	1.65	ND	1.55	679.30	ND	0.20
Bt_3	61 – 90	0.45	185.40	4.34	0.22	0.05	0.60	1.47	ND
C	91 - 120	0.67	302.40	4.72	0.11	0.15	69.40	1.26	ND
					IJESA-ISU				
Ap	0 – 20	0.15	40.40	4.02	0.15	0.13	32.90	ND	0.26
Bt_1	21 – 32	0.14	30.40	0.10	ND	0.17	18.40	ND	0.02
Bt_2	33 – 110	0.11	24.00	4.71	0.28	0.01	2.20	ND	0.30
C	111 - 150	0.14	18.90	10.33	0.15	0.10	25.00	ND	0.09
					IKERE				
Ap	0 – 23	0.27	99.30	11.67	ND	0.13	1.70	ND	0.04
Bt_1	24 – 64	0.63	307.30	3.80	ND	0.11	43.50	3.19	ND
Bt_2	65 – 92	0.20	67.90	3.35	ND	0.01	10.90	ND	ND
C	93 – 140	0.09	59.30	2.62	ND	0.10	22.10	ND	0.03
					IRE				
Ap	0 – 20	1.64	753.30	2.81	0.16	0.94	437.10	2.10	0.08
Bt_1	21 – 43	0.78	321.40	1.15	0.05	0.60	272.30	0.71	ND
Bt_2	44 – 70	0.20	56.10	2.58	0.06	0.27	45.40	0.21	0.09
C	71 – 120	0.18	36.40	0.95	0.25	0.10	29.00	3.36	0.29
					OSIN-ITAPA				
Ap	0 – 23	1.12	484.50	ND	0.02	0.24	73.60	ND	0.05
Bt_1	24 – 50	0.92	382.40	3.58	ND	0.11	52.00	4.15	0.05
Bt_2	51 – 80	0.48	191.20	5.82	0.05	0.12	23.00	3.04	ND
C	81 - 130	0.11	48.90	3.54	0.13	0.09	0.57	0.04	0.03

† ND: Not detected

Table 2c. Micronutrient status of soils developed on Charnockite in Ekiti State

Horizon	Depth (cm)	NH$_4$OAc pH 7.0			
		Mn	Fe	Cu	Zn
		------------------- mg kg^{-1} -------------------			
		ADO			
Ap	0 - 11	0.64	273.90	ND	0.08
Bt$_1$	12 – 21	0.34	145.80	2.25	ND
Bt$_2$	22 – 61	0.27	139.80	1.70	ND
Bt$_3$	62 – 118	0.17	35.00	1.44	0.08
C	119 - 150	0.79	352.10	ND	0.05
		IJAN			
Ap	0 – 20	0.34	130.10	1.60	ND
Bt$_1$	21 – 35	0.11	10.40	ND	ND
Bt$_2$	36 – 60	1.14	489.70	ND	ND
Bt$_3$	61 – 90	0.03	18.50	ND	0.03
C	91 - 120	0.07	24.50	1.70	0.02
		IJESA-ISU			
Ap	0 – 20	ND	6.00	0.83	0.20
Bt$_1$	21 – 32	0.12	17.80	0.08	0.08
Bt$_2$	33 – 110	0.12	21.00	0.56	0.02
C	111 - 150	0.07	11.60	0.07	0.13
		IKERE			
Ap	0 – 23	ND	6.00	0.83	0.20
Bt$_1$	24 – 64	0.12	17.80	0.08	0.08
Bt$_2$	65 – 92	0.12	21.00	0.56	0.02
C	93 – 140	0.07	11.60	0.07	0.13
		IRE			
Ap	0 – 20	0.94	403.30	1.88	0.01
Bt$_1$	21 – 43	0.49	207.50	ND	0.29
Bt$_2$	44 – 70	0.16	58.00	1.48	ND
C	71 – 120	0.08	14.90	0.67	ND
		OSIN-ITAPA			
Ap	0 – 23	0.04	17.50	0.91	ND
Bt$_1$	24 – 50	0.08	24.70	ND	ND
Bt$_2$	51 – 80	0.02	34.10	1.93	0.08
C	81 - 130	0.03	12.80	ND	0.02

† ND: Not detected

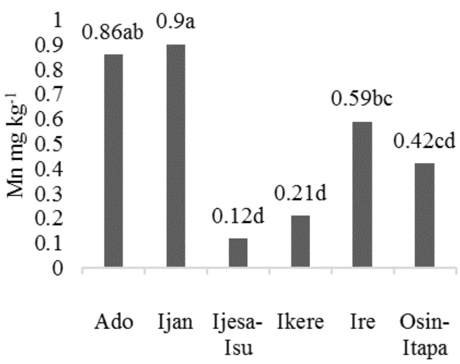

Figure 1. Mean of extractable Mn across the locations

†Mean with the same letter are not significantly different.

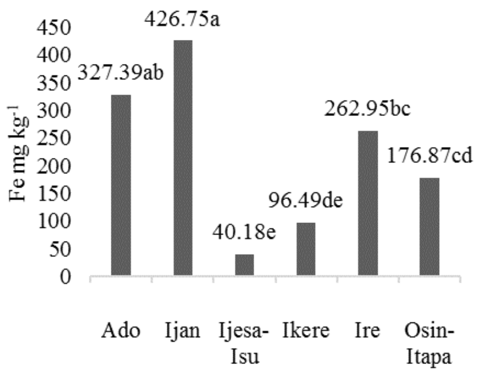

Figure 2. Mean of extractable Fe across the locations

†Mean with the same letter are not significantly different.

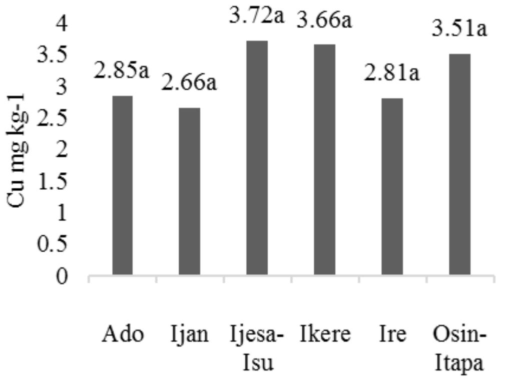

Figure 3: Mean of extractable Cu across locations

†Mean with the same letter are not significantly different.

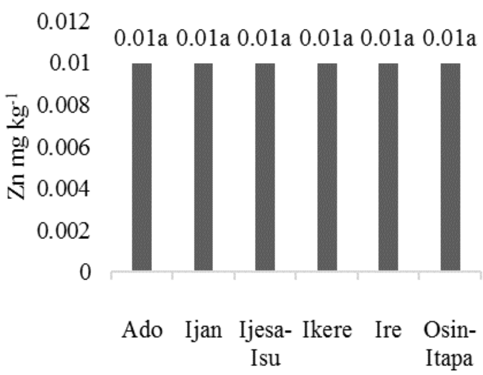

Figure 4. Mean of extractable Zn across the locations

†Mean with the same letter are not significantly different.

Table 3. Relationship between the selected extractable micronutrients and some soil properties

Micronutrient	Organic carbon	pH	Clay	Fe_2O_3
Mn	0.22*	0.10^{ns}	-0.16^{ns}	0.14^{ns}
Fe	0.23**	0.15^{ns}	-0.23**	0.15^{ns}
Cu	0.01^{ns}	0.02^{ns}	-0.03^{ns}	-0.10^{ns}
Zn	0.01^{ns}	-0.02^{ns}	-0.03^{ns}	-0.08^{ns}

* and ** : Significant at 0.05 and 0.01 probability level, ns: Not significant at 0.05 probability level.

IV. Conclusion

This work provides more information about the profile distribution of the micronutrient cations in soils developed on charnockite in Ekiti State, Nigeria. The surface and sub-surface amount of the extractable Mg and Zn are generally deficient in the soils for optimum crop production but extractable Fe and Cu were adequately available in the charnockitic soils considered. The micronutrient cations distribution in the soils does not follow any particular pattern, but varies down the profiles. Activities that hasten up the mineralization of organic materials, such as slash-and-burn bush clearing, seasonal burning and tillage that expose the soil without any soil cover should be minimized in managing the soil health for an optimum nutrient availability.

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