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PROFILE DISTRIBUTION OF SELECTED ESSENTIAL MICRONUTRIENTS IN PADDY SOILS OF ABIA STATE, SOUTHEASTERN NIGERIA

AHUKAEMERE, C.M., NKWOPARA, U.N., AND EKPENYONG, O.S

Department of Soil Science and Technology, Federal University of Technology, Owerri P.M.B. 1526, Owerri, Imo State, Nigeria.

Corresponding author: mildredshine@yahoo.com.

ABSTRACT

The realization of the potentials of paddy soils necessitates taking the inventory of their micronutrients status. The available micronutrients status of soils of two varying paddy lands (upland and lowland) were studied. Random soil survey technique was used in field sampling. Four representative soil profiles, two in each paddy soil type were dug. Soil samples were collected from the profiles according to their genetic horizons for laboratory analyses and their interpretations. The results showed that Clay dominated the particle fractions of the soil. Bulk density was below the minimum bulk value at which root-restricting conditions will occur. The pH ranged from very strongly acidic to moderately acidic. Available phosphorus was acutely deficient in both soils (< 3.0 mgkg^{-1}). Iron (Fe) contents of the soils varied between 6.99 and 8.39 mgkg^{-1} in upland soils, 4.89 and 10.63 mgkg^{-1} in lowland soils. The mean values of manganese (Mn) varied between 5.50 and 10.00 mgkg^{-1} in upland soils, 5.00 and 8.90 in low land soils. Zinc (Zn) contents ranged between 1.69 and 1.88 mgkg^{-1} in upland soils, 1.69 and 3.99 mgkg^{-1} in lowland soils while copper contents had mean values of 0.11 and 0.19 mgkg^{-1} in upland, 0.15 and 0.19 mgkg^{-1} in lowland soils respectively. The distribution of the micronutrients did not follow any particular trend down the profile pits irrespective of the paddy soil types. The t-test analysis showed that Zn content in lowland soil was significantly ($p \leq 0.05$) higher than the upland soil, while the reverse was the case in Mn contents of these soils. Fe and Cu did not differ significantly in across the soils. The results of correlation analyses revealed that organic matter had significant ($p \leq 0.05$) positive correlation with Mn and Zn (r = 0.713*, r = 0.516*). Similarly, silt and total nitrogen had significant ($p \leq 0.05$) positive correlation with Mn and Zn (r = 0.685*, r = 0.554*, r = 706*, r = 502*), while negative and non-significant correlation was observed between these soil properties and Fe and Cu.

Keywords: Micronutrient, Paddy soil, Profile.

INTRODUCTION

Micronutrients deficiencies in rice growing soils are wide spread in a number of countries including Nigeria. The rapid manifestation of the deficiencies of micronutrients in paddy soils is due to anthropogenic factors, adoption of paddy varieties with high nutrients requirement and use of high-analysis fertilizers with little or no micronutrients. Fageria *et al.*, (2002) reported that intensive cropping practices, enhanced production of crops on marginal soils that contain low levels of essential micronutrients and adoption of high-yielding cultivars which have high micronutrients demand have led to increased demand for micronutrients. However, essential micronutrients are not applied regularly to the soil in conjunction with common fertilizers, yet about two to six times in quantity of these elements are removed annually from the soil than applied to it (Lawal *et al.*, 2012). Unfortunately, fertilizer application practice in Nigeria is predominantly in favour of nitrogen (N), phosphorus (P) and potassium (K). The increasing use of NPK fertilizers generally devoid of micronutrients has no doubt increased crop production including rice, but it brought with it a host of problems related to micronutrient deficiencies.

In Nigeria, paddy soils aid tremendously in ensuring food security especially production of rice which the country spend a huge amount on its importation. In order to realize the full potentials of these soils, there is need to take the inventory of their nutrient status including the essential micronutrients. A good knowledge of the variations of soil profile characteristics as it relates to micronutrient status is essential for good land evaluation which is a pre-requisite for sound land use planning. Moreover, information on the profile distribution of these elements in rice growing soils will provide the basis for making informed decision with respect to fertilization and other soil management practices. Amidst limited attention given to micronutrients in Nigeria arable soils, it becomes imperative to initiate studies on the status of these essential elements in rice growing soils. This study therefore investigates the profile distribution of selected micronutrients in paddy soils developed on Shale parent material.

MATERIALS AND METHODS

Study Area

Uzuakoli in Bende LGA, Abia State of South-eastern Nigeria is located between the Latitude 4^0 7^1N and 6^0 30^1, Longitude 7^0 54^1 and 8^0 58^1E. Soils are derived from Shale (Bende Ameki group) . The area receives an average of 2134 mm of rainfall distributed to about 139 days of the year. The daily temperature ranges from 21^oC to 34^oC. The relative humidity reaches a minimum of 60 % in January (at the peak of the dry season) and rises to 80 - 90 % in July (at the peak of the rains) (Monanu, 1975). The original vegetation of the study area was the tropical rain forest (Igbozuruike, 1975; FDALR, 1985). The rain forest has however been destroyed largely through human activities and supplanted with what is today referred to as the oil palm bush.

Field Studies

Four profile pits were sunk in two different paddy soil types namely upland and lowland. The study sites and profile pits were geo-referenced (latitude, longitude and altitude) with the aid of a hand held global positioning system (GPS).The profile pits were described using FAO, (2006) guidelines, delineation of horizon boundaries was accomplished before actual sample collection for laboratory analyses and samples were collected according to horizons. The soil samples were air dried, crushed and sieved through a 2 mm sieve mesh. A small quantity (about 10 g) of each sample was finely ground and preserved for determination of organic carbon and total nitrogen. Undisturbed soil samples for determination of bulk density were collected using core samplers.

Laboratory Soil Analyses

The physical and chemical properties of the soil samples were determined using routine analytical methods. Particle size distribution was carried out by hydrometer method (Gee and Or, 2002). Bulk density was determined using the procedure outlined by Arshad *et al.,* (1996). Porosity was computed from bulk and particle density as described by Vomocil (1965). The moisture content was determined gravimetrically. Soil pH was measured electrometrically by glass electrode in pH meter in distilled water suspension using a soil: liquid ratio of 1: 2.5 (Thomas, 1996). Exchangeable basic cations were extracted with neutral ammonium acetate (NH_4OAc) (Jackson, 1962). Exchangeable acidity was extracted with KCl (1 N) and measured titrimetrically according to the procedure of Mclean (1982). Effective Cation Exchange Capacity (ECEC) was the sum of the exchangeable bases and the exchange acidity, while base saturation, was computed as the percentage of the ratio of exchangeable bases to ECEC. Soil Organic carbon (SOC) was determined by Walkley and Black digestion method (Nelson and Sommers, 1982). Total Nitrogen was estimated by micro-Kjeldahl digestion method (Bremner and Mulvaney, 1982) while available phosphorus was determined by Bray II Method (Olsen and Sommers, 1982). Available micronutrients (Fe, Zn, Mn and Cu) were extracted with 0.1N HCl, and determined by the use of Atomic Absorption Spectrophotometer (AAS).

Data Analysis

Data generated were subjected to mean, coefficient of variation and correlation analyses. Paired t-test was used to compare the means, significant means were separated at 5% probability level. The coefficient of variation was ranked according to the procedure of (Wilding, *et al*., 1994) where Cv $\leq$ 15% = low variation, Cv $\geq$15 $\leq$ 35% = moderate variation, Cv > 35 % = high variation.

RESULTS AND DISCUSSION

Physico-chemical properties of soil

The results of the physical and chemical properties of soils are shown in Table 1. The particle size analysis revealed that all the horizons irrespective of the soil types have clay texture. Silt contents of the soils decreased with soil depth with exception of profile 1 of the lowland soils while the distribution of sand and clay did not follow a uniform trend down the profile pits. The moderate silt content (181 – 210 gkg^{-1}) observed in this study contradicts the assertion of Akamigbo (1984) that soils of South eastern Nigeria are low in silt as a result of the high degree and extent of weathering and leaching they have undergone. The soil texture reflected the nature of the parent material from which the soils were developed. Variability in clay distribution down the profile pits was low (cv $\leq$ 15%) with exception of profile pit 2 of lowland with moderate variation (cv > 15%). The trend of clay distribution down the profile observed in this study contradicts the reports of several authors in Nigerian soils (Udoh *et al*., 2008, Chikezie *et al*., 2009) who reported increased clay content with soil depth.

Bulk density of the soils ranged from 1.38 to 1.50 gcm^{-3} and increased regularly with depth in all the profile pits. Least bulk density values were recorded in the surface horizons with corresponding high organic matter revealing the influence of organic matter on soil compaction. Several authors have reported the significant influence of organic matter on soil bulk density (Akamigbo, (1999), Ahukaemere, (2012). Results of bulk density were less than the critical limits for root restriction (1.75 – 1.85 gcm^{-3}) (Soil Survey Staff, 2003). Soil pH ranged from 4.34 – 5.31 and did not follow definite sequence in its distribution within the profiles. The total nitrogen contents of the soils ranged from 1.43 -1.58 gkg^{-1} while the organic matter content of the soils ranged between 29.00 to 33.00 gkg^{-1}. Total nitrogen and organic matter contents of the soils decreased down the profiles in all the soils investigated. This could be due to the application of both organic and inorganic fertilizers on the soil surface by farmers. In addition, high nitrogen content of the surface horizons indicates little or no leaching losses in these soils, and could be attributed to the clayey nature of the soils. However, the results of coefficient of variation analysis showed that both total nitrogen and organic matter showed high variation (cv > 35%) in all the profile pits studied. The available P content of the soil was extremely low (0.98 – 2.18 mgkg^{-1}) compared to the critical value of 15 mgkg^{-1} (Enwezor *et al*., 1990) and may be partly due to the availability of Zn and Mn in the soils investigated. The average P content of the soils showed high variation in all the soils with exception of profile 2 of the upland soils that varied moderately (Table 1).

Table 1: Physico-chemical Properties of Upland and Lowland Paddy Soils

Horizon	Sand (gkg^{-1})	Silt (gkg^{-1})	Clay (gkg^{-1})	Tex.	BD (gcm^{-3})	MC (%)	TP (%)	pH (H_2O)	OM gkg^{-1}	TN gkg^{-1}	Av. P mgkg^{-1}	TEA (cmolkg^{-1})	TEB (cmolkg^{-1})	ECEC (cmolkg^{-1})	BS %
Upland profile 1															
Ap	92.0	280.0	628.0	C	1.34	5.80	49.40	5.20	65.00	3.2	2.63	0.30	5.38	5.68	94.7
AB	52.0	160.0	788.0	C	1.37	6.63	48.30	4.84	31.00	1.5	3.86	2.90	4.3	7.20	59.7
Bt1	112.0	146.0	748.0	C	1.41	11.03	46.79	4.75	20.00	0.9	1.23	1.50	2.89	4.89	59.1
Bt2	101.0	140.0	759.0	C	1.86	8.60	29.81	4.76	19.00	0.7	1.0	2.43	2.50	3.93	63.6
Mean	**89.25**	**181.5**	**730.8**	**C**	**1.495**	**8.015**	**43.58**	**4.89**	**33.0**	**1.58**	**2.18**	1.78	**3.77**	**5.43**	**69.3**
Cv (%)	29.3	36.5	9.7		16.4	29.0	21.2	4.40	65.00	72.10	61.10	38.00	35.10	25.50	24.60
Upland profile 2															
Ap	92.0	240.0	668.0	C	1.24	5.96	53.96	5.19	63.00	3.1	1.39	0.60	7.25	7.85	92.3
AB	232.0	200.0	568.0	C	1.24	8.20	53.20	5.19	32.00	1.6	0.76	1.40	3.65	5.03	73.1
Bt1	142.0	190.0	668.0	C	1.41	12.07	46.79	4.5	11.00	0.9	0.89	2.10	2.96	4.25	69.6
Bt2	152.6	180.0	668.0	C	1.62	16.30	38.87	4.46	8.2.00	0.4	0.87	2.30	5.01	5.26	50.4
Mean	**154.65**	**202.5**	**643.0**	**C**	**1.38**	**10.63**	**48.21**	**4.85**	**29.00**	**1.5**	**0.98**	1.60	**4.72**	**5.60**	**71.4**
Cv (%)	37.5	13.0	7.8		13.1	42.7	14.5	12.20	87.90	78.30	28.70	41.11	40.1	27.90	24.10
Lowland profile 1															
Ap	132.0	260.0	608.0	C	1.21	5.19	54.33	5.4	55.00	2.7	3.81	0.40	6.42	8.82	94.1
AB	252.0	200.0	548.0	C	1.51	9.00	43.01	5.33	44.00	2.1	1.09	0.70	9.41	10.11	93
Bt1	372.0	120.0	508.0	C	1.55	9.99	41.5	5.24	12.00	0.6	1.31	0.70	2.69	3.39	79.3
Bt2	172.0	180.0	648.0	C	1.67	15.59	36.9	5.27	6.80	0.3	0.52	0.30	1.95	2.25	86.6
Mean	**232.0**	**190.0**	**578.0**	**C**	**1.485**	**9.94**	**43.94**	**5.31**	**29.0**	**1.43**	**1.68**	0.53	**5.12**	**6.14**	**88.3**
Cv (%)	45.6	30.4	10.8		13.2	43.2	16.8	1.30	80.3	81.30	86.00	26.20	67.70	63.50	7.70
Lowland profile 2															
Ap	152.0	300.0	548.0	C	1.15	53.2	56.6	4.66	64	3.2	0.86	1.80	5.56	7.36	75.5
AB	232.0	200.0	568.0	C	1.19	128.2	55.09	5.3	25	1.12	2.63	0.70	3.64	4.34	83.8
Bt1	72.0	180.0	748.0	C	1.57	176.2	40.75	5.24	21	1.00	2.69	0.70	5.15	5.85	88.00
Bt2	112.0	160.0	728.0	C	1.7	166.4	35.84	5.46	10	0.50	0.91	0.40	3.41	4.61	74.00
Mean	**142.0**	**210.0**	**648.0**	**C**	**1.403**	**13.10**	**47.07**	**5.17**	**30.0**	**1.46**	**1.77**	0.90	**4.44**	**5.54**	**80.3**
Cv (%)	48.1	29.6	16.1		19.5	42.6	22.0	6.80	78.3	82.1	57.8	37.10	24.20	24.90	8.40

Cv = Coefficient of variation, Cv $\leq$ 15% = low variation, Cv > 15 $\leq$ 35% = moderate variation, Cv >35% = high variation, BD = Bulk density, OM= Organic Matter Av.P= Available phosphorus, TEB = Total exchangeable bases, ECEC= effective cation exchange capacity, TN = Total nitrogen, MC = Moisture content, TP = Total porosity, Tex. = Textural class, TEA = Total exchangeable acidity, C = Clay.

Soil micronutrients

The micronutrient contents of the soils are presented in Table 2 and 3. The available manganese (Mn) contents of the soils ranged from 5.00 – 10.00 $mgkg^{-1}$. The overall average values of Mn were 7.7 $mgkg^{-1}$ in upland soils and 6.95 $mgkg^{-1}$ in lowland soils respectively. Mn content of the upland soils was significantly ($p \leq 0.05$) higher than that of lowland soils (Table 3). Higher values of Mn in upland (better drained) soils may be due to higher mobility of Mn when compared with Fe under less reducing condition (Onweremadu *et al*., 2007). However the proportion of available Mn obtained in this study was high compared to the critical value (1.00 $mgkg^{-1}$) reported by Udoh *et al*., (2008). In view of this, all the soils are therefore regarded as adequate in available Mn. The values of available Mn reported in this study were generally higher than the value reported by Onweremadu *et al*., (2007) in some wetland soils of Southeastern Nigeria. High availability of Manganese in these soil may be attributed to pH, clay and organic matter contents of the soils. Although the distribution of manganese down the pedon did not follow a uniform trend, the epipedons (mainly the Ap horizons) of all the pedons contained higher quantity of available Mn than the argillic (Bt) horizons. However, high concentration of available Mn at the surface horizons may be a reflection of the organic matter contents of these horizons. The results of coefficient of variation (Cv) showed high variation (cv > 35%) in the distribution of Mn in all the profile pits irrespective of the paddy soil type. In addition, correlation analysis results showed significant positive correlation between Mn and organic matter ($r = 0.713$) ($p \leq 0.05$).

The available zinc (Zn) contents of the soils ranged from 1.39 – 3.99 $mgkg^{-1}$. The overall average values of Zn were 1.79 $mgkg^{-1}$ in upland soils and 2.99 $mgkg^{-1}$ in lowland soils with soils of the lowland containing significantly ($p \leq 0.05$) higher proportion. The proportion of available Zn obtained in this study was above the critical level of 0.8 $mgkg^{-1}$ (Lindsay and Norvel, 1978) and 0.5 $mgkg^{-1}$ (Udoh *et al*., 2008). The Zn contents of both soils were rated medium to high and are fairly adequate for rice production. Availability of Zn in the studied soils may be partly due to low available phosphorus, low pH and high clay content of the soils. FAO, (2008) reported Zn deficiency in soil with high pH (pH > 7.5), low clay and low organic matter. Also, the significant influence of clay, pH, phosphorus and organic matter had been reported by several authors (Lawal *et al*., 2012, Lake 2000). However, complexes are formed under acidic pH range (Isirimah *et al*., 2003) and the element sorbs thereby becoming unavailable when soils become alkaline (Tinker and Lauchi, 1984).

Table 2: Available Micronutrient Contents of Upland and Lowland soils

Horizon	Mn (mgkg^{-1})	Fe (mgkg^{-1})	Zn (mgkg^{-1})	Cu (mgkg^{-1})
		Upland profile pit 1		
Ap	24	1.15	2.8	0.05
AB	8.8	6.85	1.4	0.05
Bt1	5.0	9.85	1.3	0.15
Bt2	4.2	10.1	1.26	0.2
Mean	**10.0**	**6.99**	**1.69**	**0.11**
CV (%)	87.6	59.6	43.9	66.7
		Upland profile pit 2		
Ap	8.9	8.3	4.3	0.2
AB	7.3	6.85	1.65	0.05
Bt1	2.6	10.2	0.9	0.25
Bt2	3.2	8.2	0.65	0.25
Mean	**5.50**	**8.39**	**1.88**	**0.19**
CV (%)	55.8	16.4	89.2	50.5
		Lowland profile pit 1		
AP	8.3	7.2	1.45	0.15
AB	4.3	8.1	1.30	0.2
Bt1	3.6	2.4	1.4	0.1
Bt2	4.0	1.85	1.45	0.15
Mean	**500**	**4.89**	**1.69**	**0.15**
CV (%)	42.9	65.9	6.1	27.2
		Lowland profile pit 2		
AP	13.0	9.95	5.55	0.15
AB	6.9	10.25	5.8	0.17
Bt1	12.0	17.65	3.6	0.25
Bt2	4.1	4.65	1.0	0.2
Mean	**8.90**	**10.63**	**3.99**	**0.19**
CV (%)	42.9	65.9	6.1	27.2

Cv = Coefficient of variation, Cv $\leq$ 15% = low variation, Cv > 15 $\leq$ 35% = moderate variation, Cv >35% = high variation, Fe = Iron, Mn = Manganese, Zn = Zinc, Cu = Copper.

Table 3: t- test for the equality of means of soil available micronutrients between upland and lowland soils ($p < 0.05$)

Soil type	Mn (mgkg^{-1})	Fe (mgkg^{-1})	Zn (mgkg^{-1})	Cu (mgkg^{-1})
Upland	7.75	7.69	1.79	0.15
Lowland	6.95	7.76	2.99	0.34
Remarks	S	NS	S	NS

S = Significant, NS = Not significant, Fe = Iron, Mn = Manganese, Zn = Zinc, Cu = Copper.

In lowland soils, Zn was irregularly distributed down the profile pits while in upland soils, it consistently decreased down the pits. However, the surface horizons (A and AB) contained higher quantity of Zn irrespective of the soil types. Similarly, high proportion of Zn in these horizons could be due to high organic matter contents of the soils. Organic matter had significant positive relationship with Zn (r = 0.516*). High variation was observed in the profile distribution of Zn in upland soils while the reverse was the case in the lowland soils.

The proportion of iron (Fe) in the two paddy soils ranged from 4.89 to 10.63 $mgkg^{-1}$. The average values of Fe in the upland and lowland soils were 7.69 and 7.76 $mgkg^{-1}$ respectively. No significant difference was observed in the iron contents of the different soil types studied. The values of iron obtained in this study were high compared to the critical value of 4.5 reported by Lindsay and Norvel, (1978). The concentration of iron was highest in the middle horizons in both soils. Similar trend of distribution had been reported by Onweremadu *et al*., (2007) in some wetland soils of South eastern Nigeria. High variation was recorded in all the pedons in lowland and pedon 1 of the upland soils. These high variabilities are speculated to be due to differences in the formation of organo-metal complexes which have subsequently altered the Fe solubility.

The available copper (Cu) contents of soils are shown in Table 2 and 3. The overall mean Cu contents of the studied soils varied between 0.15 and 0.34 $mgkg^{-1}$. Soils of the lowland contained available Cu which was higher than the critical value of 0.2 $mgkg^{-1}$ (Sims and Johnson, 1991) while the reverse was the case in soils of the upland. Generally, available Cu reported in this study was low when compared with the value reported by Lawal *et al*., (2012) and Adeboye, (2011) in hydromorphic soils of Nigeria, but within the range reported by Mustapha and Singh (2003). However, Cu did not show significant relationship with soil properties across the soils studied.

Table 4: Correlation between Soil Micronutrients and Soil Physico-chemical properties

*=significant at 5%, ** = significant at 1%, ns = not significant

Soil Property	Cu	Mn	Fe	Zn
% Moisture Content	0.56728	-0.4336ns	0.2221ns	-0.204ns
Available P	-0.312ns	0.45381ns	0.12018ns	0.18919ns
Bulk Density	0.3787ns	-0.4322ns	-0.0671ns	-0.5867*
Clay	0.2291ns	-0.0580ns	0.31799ns	-0.2912ns
ECEC	0.0103ns	0.26716ns	0.22593ns	0.16865ns
OM	-0.3308ns	0.71323**	-0.0488ns	0.51584*
Sand	-0.1567ns	-0.3645ns	-0.3141ns	-0.0371ns
Silt	-0.1394ns	0.68493**	-0.0327ns	0.55406*
TEA	0.13580ns	0.30383ns	0.16957ns	0.23099ns
TN	-0.3158ns	0.7056**	-0.0499ns	0.50147*
Total Porosity	-0.3719ns	0.4306ns	0.06905ns	0.59081**
pH (water)	-0.2718ns	0.0340ns	-0.2029ns	-0.2082ns

CONCLUSION

Currently, the status of available Fe and Mn in both upland and lowland soils are adequate for rice production. Copper deficiency was observed in upland soils while its concentration in lowland soils was fairly adequate. Also, both paddy soil types contained available Zn that can support rice production. However, for optimum rice performance, both soil types require Cu-fertilizer application while intensive cropping in the same soils after a few years without organic or inorganic fertilizer that is enrich with Zn may apparently lead to Zn-deficiency.

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