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PHOSPHORUS STATUS IN SOME SOILS OF MID-WESTERN AGRO-ECOLOGICAL ZONE OF NIGERIA

Orhue, Ehi Robert and John Kingsley

Department of Soil Science, Faculty of Agriculture, University of Benin, Benin City, Edo State, Nigeria

Corresponding author email: orhuerob@yahoo.com

ABSTRACT

The trial was carried out to determine the status of various forms of P in soils formed on 3 types of parent materials in Southern Nigeria. Soil samples were obtained from3 ha area in each of the locations at 0-15 cm and 15-30 cm depth and then subjected to routine physical and chemical analysis. Result revealed that the sand component of the soils which ranged from 771 gkg^{-1} to 892 gkg^{-1} decreased with increased soil depth. The highest sand content was obtained at 0-15 cm top soil of coastal plain sand parent material. The clay and silt fractions ranged from 75 gkg^{-1} to 155 gkg^{-1} and 33gkg^{-1} to 74 gkg^{-1} respectively. Both the clay and silt increased with increased soil depth in all the parent materials. The soil pH, organic carbon and organic matter also decreased with increased soil depth ranging from 5.50 to 6.60, 2.10 gkg^{-1} to 3.15gkg^{-1} and 5.52gkg^{-1} to 9.40 gkg^{-1} respectively. The available P by Bray P-2 extractant was higher in the soils of the 3 parent materials compared to that of Bray P-1 extractant. The various P forms also decreased with increased soil depth. The Al-P, Fe-P, Sal-P and Red-P were higher in 0-15 cm top soil of alluvium parent material while the Res-P, Ca-P, Occ-P, Org-P and Total P were higher in the 0-15 cm topsoil of basement complex soil. Of all the various forms of P, Org-P occupied a higher percentage in the total P component of the soil. The soil pH positively significantly correlated with Occ-P, Res-P and Org-P while organic carbon positively significantly correlated with Occ-P and Res-P. The organic matter positively significantly correlated Occ-P, Res-P, Org-P and Total P. The clay and silt fractions positively significantly correlated with Al-P whereas the sand component of the soil positively significantly correlated with the Ca-P.

Keywords: Alluvium, Basement complex, Distribution, Parent materials, Phosphorus, Shale.

INTRODUCTION

Phosphorus (P) is one of those major elements required for biological activity in plants. Although the total P content in most soils can be large , only a small fraction is available or in an organic form for biological utilization because it is bounded either to incompletely weathered mineral particles, adsorbed on mineral surfaces or over the time of soil formation, made available by secondary mineral formation(Yang et al, 2013). Sometimes, it is precipitated by dissolved Al or Fe at low pH. The forms and distribution of P in agricultural soils may indicate soil P processes and possibilities for sustainable production using the soil P reserves(Ulenand Snall, 2007). The relative distribution of P varies with climate, vegetation, parent material and soil types (Indianti and Sharpley, 1998) and that the distribution of P is closely related to the pedogenetic evolution of soils with the mature soils having low P status (Kleinman et al, 1999)

The P exists in soils in organic and inorganic forms. The organic forms of P are found in humus and other organic materials. The P in organic materials is released through mineralisation process involving soil organisms. The inorganic forms exist as calcium phosphate (Ca-P), Aluminium phosphate(Al-P), iron phosphateFe-P), reductant soluble phosphate(Red-P) Saloid-bound phosphate(Sal-P),and occluded phosphate (Occ-P). The relative abundance of inorganic P forms is indicative of the degree of weathering sequence being in the order of Ca-P >Al-P> Fe-P>Occluded-P (Westing and De-Brito, 1969). The distribution of active P fraction namely Al-P, Fe-P and Ca-P and their abundance in soil are dependent on pH, the solubility product of the different phosphate, parent material, cations present and degree of weathering(Kleinmanet al, 1999).

Information on P fertility status is of great importance since it helps determine the level of fertilizer to be applied to crops. The information is equally useful for P fertilizer distribution and planning at both local and national levels of the country. The forms in which P exists determines the relative availability to crops and also it enables determine the speciation and management of such soils. Therefore,the trial was conducted to determine the various forms and distribution of P as well as factors influencing their distribution in the selected soils.

MATERIALS AND METHODS

Forty-two(42) soil samples were obtained from 0-15 cm and 15-30 cm depth at three locations namely Sobe and Ekpoma in Edo State and Sapele in Delta State of Nigeria. The Sobe, Ekpoma and Sapele represent alfisol, ultisol and oxisol respectively. At each location, a 300 m x 300 m area dimension was measured and points to be sampled were determined without considering the vegetation and slope of the area.

Sobe sampling site is about 102 km from Benin City the State capital and is located at an elevation of 70 m above sea level. The area is situated in the derived savannah of Nigeria. The area lies between Latitude 6^{O} 59N and longitude 5^{O} 42'E. It is an agrarian town in derived savannah zone. Soils from this area are derived from basement complex

Sapele is located in the latitude 5^{O} 55'N and longitude 5^{O} 42'E. Its geographical coordinates lies in the rainforest zone with bimodal rainy season. The peak of rainy season is June with a break in August. The dry season starts in October till early March. The major occupation include fishing farming and trading. Sapele has alluvium as parent material

Ekpoma geographical coordinates is latitude 6^{O} 45'N and longitude 6^{O} 08'E. The town is a transition zone between rainforest zone and savannah zone. It is situated at 332 m above sea level. The dry season lasts between November and March while the rainy season lasts between March and October with a peak at July and a break in August. It is also an agrarian town. Ekpoma soil is formed on coastal plain sand

Laboratory Analysis

The soil samples collected were air-dried at room temperature for about a week, crushed to pass through a sieve of 2 mm. The particle size distribution was determined by methods of Gee and Or (2002). The pH was determined in KCl solution at a ratio of 1: 2 (Soil:KCl) using a glass electrode meter. The organic carbon was

Table 1: Physico-chemical properties of the soils (mean ± standard Deviation)

Locations	Depth(cm)	Parent materials	pH	Sand (gkg^{-1})	Silt (gkg^{-1})	Clay (gkg^{-1})	Organic Carbon (gkg^{-1})	Organic Matter (gkg^{-1})	BrayP-2 mgkg^{-1}	Bray P-1 mgkg^{-1}
Sobe	0-15	Basement complex	6.60±0.60	835±5.00	40±1.00	125±5.00	3.15±0.15	9.40±0.40	7.59±0.09	5.48±0.08
	15-30		6.50±0.50	808±8.00	57±1.00	135±5.00	2.25±0.25	6.67±0.07	6.34±0.04	5.41±0.01
Sapele	0-15	Alluvium	5.57±0.49	829±9.00	51±1.00	120±5.00	2.31±0.05	6.30±0.10	8.57±0.07	7.93±0.03
	15-30		5.60±0.60	771±1.00	74±4.00	155±5.00	2.19±0.10	6.23±0.03	7.20±1.00	6.58±0.08
Ekpoma	0-15	Coastal Plain Sand	5.50±0.50	892±2.00	33±3.00	75±5.13	2.93±0.03	8.69±0.09	6.86±0.06	4.90±0.05
	15-30		5.50±0.50	830±5.00	50±5.00	120±1.00	1.86±0.06	5.52±0.02	4.79±0.09	4.36±0.06

determined by methods of Udo et al (2009). The value obtained in organic carbon was multiplied by a factor of 1.729 to achieve organic matter component of the soil. The available P was determined by both Bray P-1 and Bray P-2 extractions (Bray and Kurtz, 1945) while the sequential fractionation of inorganic phosphorus and the organic P forms were carried out by methods of Udo et al (2009). The P in the extracts was determined calometrically by the molybdenum blue colour method of Murphy and Riley (1962). The mean and standard deviation calculated and correlation coefficient between some soil properties and forms of P were determined.

RESULTS AND DISCUSSION

Physico-chemical properties of the soils used in the trial

Some physico-chemical properties of soils used are shown in Table 1. The sand component ranged from 771to 892 gkg^{-1} and decreased with the corresponding increase in the soil depth in all the locations. The highest sand content was however achieved in the 0-15 cm topsoil of Ekpoma coastal plain sand. The clay section of the soils under investigation ranged from 75 to 155 gkg^{-1} while that of the silt ranged from 33 to 74 gkg^{-1}. The clay and silt content of the soils increased with increased soil depth in all the locations with the highest clay and silt components recorded at alluvium parent material. The low clay content at surface 0-15 cm depth may be due to the sorting of soil materials by biological and agricultural activities, clay content migration or combination of these activities as earlier reported by Malgwi et al (2000) and Adegbenro-et al (2011). While the low silt content in all the surface soils of the three locations is in line with the reports of Okusanmi and Oyediran(1985) and Adegbenroet al (2011).

The pH of the soils also decreased with increased soil depth and the soil pH ranged from 5.50 to 6.60. The highest pH value of 6.60 and 6.50 were obtained in 0-15 cm and 15-30 cm soil depth respectively at basement complex parent material compared to other parent materials. The acidic conditions in the coastal plain sand and alluvium parent materials could be attributed to the presence of higher exchange acidity and higher rainfall in the area which render the soil prone to erosion and high base leaching as reported earlier by Udo et al (2009) and Adeg-

Table 2: Forms and distribution P in the soils (mean ± standard Deviation)

Location	Depth (cm)	Parent materials	Sal-P	Al-P	Fe-P	Ca-P	Red-P	Occ-P	Res-P	Org-P	Total P
			←				mgkg^{-1}				→
Sobe	0-15	Basement complex	0.18±0.02	0.49±0.09	1.61±0.01	0.54±0.04	1.04±0.04	0.95±0.05	3.06±0.06	6.33±0.03	14.20±0.20
	15-30		0.10±0.02	0.37±0.07	0.94±0.04	0.39±0.09	0.61±0.01	0.47±0.07	1.89±0.01	6.12±0.02	10.89±0.02
Sapele	0-15	Alluvium	0.27±0.02	1.60±0.05	3.60±0.05	0.22±0.02	2.09±0.09	0.23±0.03	1.47±0.02	5.05±0.05	14.53±0.03
	15-30		0.27±0.02	0.43±0.03	1.48±0.08	0.10±0.02	1.70±0.05	0.13±0.03	1.23±0.02	4.28±0.02	9.62±0.02
Ekpoma	0-15	Coastal Plain Sand	0.14±0.02	0.29±0.09	0.80±0.05	1.60±0.05	0.36±0.02	0.25±0.02	1.74±0.04	3.85±0.05	9.03±0.03
	15-30		0.12±0.02	0.25±0.05	0.47±0.07	1.10±0.02	0.26±0.01	0.14±0.02	1.21±0.02	3.16±0.01	6.72±0.02

benro et al (2011). The basement complex soil at Sobe on the other hand is located in derived savannah region with reduced bse leaching capacity.

The organic carbon content of the soils indicated a decrease with increased soil depth and ranged from 1.86to 3.15 gkg^{-1}. The highest organic carbon component was obtained at Sobe basement complex 0-15 cm surface soil compared to other locations. The organic matter component the soils decreased with increased soil depth in all the locations.The organic matter ranged from 5.52 to 9.40 gkg^{-1} with the highest organic matter component recorded at Sobe.

The Bray P-2 available P ranged from 4.88to 8.57 mgkg^{-1} while that of Bray P- 1 available P range from 4.36 to 7.93 mgkg^{-1} in all the soil types. In both extraction methods the alluvium type of soil had the highest available P. Generally, the extractable available P decreased with corresponding increase in soil depth. The higher extractable P in the surface 0-15 cm soil depth in all the 3 types of soil could be ascribed to the presence of higher organic matter content of the soils. The available P contents in all the soils were however below the critical limit of 10 mgkg-1 (Enwezor et al 1989,Uponi and Adeoye, 2000). This low available P component of the soils could be due to the fixation of P by Fe and Al sesquioxides and pH status of the soil as earlier reported by Uzoho and Oti (2004) and Adegbenro et al (2011).

Forms and distribution P in the soils

The forms and distribution of P are shown in Table 2. The saloid P ranged from 0.10mgkg-1 from 0.27 mgkg^{-1} and decreased with corresponding increase in the soil depth. The highest saloid P was however obtained at 0-15 cm depth of alluvium soil. The reductant soluble P also decreased with increased soil depth in all the locations. Again, the alluvium soil in Sapele had the highest reductant P compared to basement complex and coastal plain sand soils. The residual P which decreased with increased depth ranged from 1.21 to 3.06 mgkg^{-1}.The highest values of residual P were achieved at basement complex soil at Sobe.

The inorganic P such as Al-P, Fe-P, Ca-P and occluded –P decreased with increased soil depth. The Al-P, Fe-P, Ca-P and occluded-P ranged from 0.25 to 160 mgkg^{-1}, 0.47 to 3.60 mgkg^{-1}, 0.10 to 1.60 mgkg^{-1} and 0.13 to 0.95 mgkg^{-1} respectively. Of all the inorganic P reported, the Fe-P was found to be higher in all the soils probably due to the presence of abundant Fe in the parent materials. This higher Fe-P obtained is

Table 3: Correlation coefficient (r) between some soil properties and the forms of phosphorus

Soil properties	Sal-P	Al-P	Fe-P	Ca-P	Red-P	Occ-P	Res-P	Org-P	Total P
pH	-0.188	0.083	0.158	-0.435	0.067	0.867*	0.797*	0.964*	0.670*
Organic carbon	0.168	0.339	0.419	0.137	0.183	0.622*	0.723*	0.487	0.484
Organic matter	0.166	0.334	0.415	0.135	0.183	0.631*	0.731*	0.591*	0.690*
Sand	-0.416	-0.060	-0.143	0.852*	-0.498	0.120	0.250	-0.200	-0.047
Silt	0.447	0.501*	0.108	-0.743	0.484	-0.405	-0.505	-0.024	-0.129
Clay	0.381	0.635*	0.156	-0.872	0.485	0.036	-0.101	0.311	0.140

*Significant at 5% level of Probability

similar to the report of Adegbenroet al (2011).

The organic P which deceased with increased depth of the soil ranged from 3.16 to 6.33 $mgkg^{-1}$. The organic P constituent in the total P at the top 0-15 cm depth soils in basement complex, alluvium and coastal plain sand soils were 44.58% 34.76% and 42.64% respectively while the 15-30 cm depth were 56.20%, 44.49% and 47.02% for basement complex, alluvium and coastal plain sand soils respectively. The abundance of organic P in the total P was due to the higher amount of soil organic matter. This result is similar to that of Adegbenro et al (2011) and further strengthens that of Omotoso and Wild (1976) who reported that organic P components ranged from 20-70% of the total P in South Western Nigeria.

The Total P which decreased with increased soil depth in the 3 locations ranged from 6.72to 14.53 $mgkg^{-1}$ with 0-15 cm top soils having the highest total P constituent probably due to high organic matter level. The total P components obtained in this trial were low compared to the values of 418.70 to 763.10 $mgkg^{-1}$ obtained by Adegbenro et al(2011) in Mica schist soil, 217 to 638 $mgkg^{-1}$ reported by Uzuet al (1975) in basement complex soil and 191 to 243 $mgkg^{-1}$ discovered by Laganathan and Sutton (1987) in sedimentary soil. The low level of total P may be attributed to the presence of hydrous metal oxides of iron and aluminium and clay and the pH status of the soils.

Correlation coefficient between some soil properties and forms of P in the soils

Table 3 shows the correlation coefficient between some soil properties and the forms of P in the soils under investigation. The soil pH positively significantly correlated with occluded P (r = 0.867), residual P (r = 0.797) and organic P (0.964) indicating that soil pH has a greater on these forms of P. The result further revealed that the organic carbon positively significantly with occluded P (r = 0.622) and residual P (r= 0.722) while the organic matter positively correlated with occluded P (r = 0.630), residual P (r = 0.730), organic P (r = 0.590) and total P (r= 0.690). The sand fraction of the soils positively correlated with Ca-P (r = 0.850) while the positively significant value between silt and Al-P was r = 0.501. The clay content of the soils was also positively significant with Al-P(r = 0.635. The exhibition of positive correlation between occlude P, residual P, Organic P, Total P and organic matter is an indication that organic matter have greater influence on organic P as well as the entire soil P component. Similar results have earlier been reported by Agboola and Oko (1976) and Ohaeri and Eshett (2011).

CONCLUSION

The trial reveals that the P forms and distribution varies with parent materials and also decreased with increased soil depth. The total P in this trial was however below the critical limit suggesting that fertilizer could be used to boost the level of P in the soils under investigation. The result further showed that organic matter has greater influence on the P component of the soils and that higher available P could be extracted from the soils using the Bray P-2 extractant.

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