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Forms and Status of Phosphorus in Soils Derived from Varying Parent Materialsin Cross River State, Nigeria.

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Abstract: *The forms and status of Phosphorus in soils derived from varied parent materials in Cross River State were examined. The study involved soil sampling at 0-15cm depth from five locations representative of soils formed from coastal plain sand (CPS), shale (SH), basement complex rocks (BCR) sandstone (SS) and basaltic rocks (BAR). The soils were analyzed for the various forms of P and routine soil properties using standard procedures. The results obtained indicated that total P varied widely due to the nature of parent materials and ranged from mean value of 76.8mg/kg in sandstone to mean value of 290.9mg/kg in shale with the order of relationship being SH > BAR > BCR > CPS >SS. Organic–P varied widely ranging from mean value of 22. 8 mg/kg in sandstone to 99.7mg/kg in shale and in the order SS < CPS < BCR <BAR < SH. The relative abundance of the active P forms were in the order of Fe–P > Al–P > Ca–P in all the soils except those formed from shale where Ca–P was more abundant. Same trend in distribution was observed for total active and total inorganic–P forms being in the order SS < CPS < BCR < BAR < SH. Available P extracted by the two methods correlated strongly with the other P forms. Bray P–2 method removed larger amount of P than Bray P-1 and the soils varied remarkable in their available P contents. Available P indices of 8mg/kg (Bray-1) and 15mg/kg (Bray–2) showed that soils derived from shale and basaltic rocks were high and well endowed with Plant available P whereas the soils formed on coastal plain sand, basement complex rocks and sandstones were relatively low and deficient in P content and would certainly require P fertilization for optimum crop production. The levels of P in these soils informed the need for proper understanding of the various forms of P to enhance soil P management and judicious fertilizer Usage.*

Keywords*: Phosphorus forms, Soils, Parent materials, Cross River State, Nigeria.*

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I. Introduction

Phosphorus (P) is a key component of cellular compounds vital to plant and animal life. It is the second most critical element in natural and agricultural ecosystems (Onweremadu, 2007), and influences plant growth and production throughout the world (Agbede, 2009). It is next to nitrogen considering its importance for profitable crop yields (Brady and Weil,2008). phosphorus (P) is known to be the most limiting nutrient element in the soil due to its high disposition to fixation by several soil constituents (Osodeke and Ubah, 2006., Ibia and Udo, 1993). Phosphorus exists in soils in organic and inorganic forms (Kuo, 1996). The organic P fraction may be derived from plant residues and from soil flora and fauna tissue and residues that resist rapid hydrolysis (Condron *et al*, 1990). Phosphorus availability to plants is usually associated with the relative abundance of the various chemical forms of the element in soils. The inorganic phosphates in soils have been classified into calcium phosphate (Ca- P), iron phosphate (Fe-P), aluminum phosphate (Al-P) and occluded Phosphate (Occ-P)(Osodeke and Ubah, 2006, Ibia*et al*, 2008). These phosphate fractions occur in all soils, butdiffers in proportion in relative to soil characteristics and parent materials. The various forms of P are dependent on many variables such as soil type, the biological components of the soils and numerous chemical and mineralogical properties including pH, Organic matter content, calcium carbonate content, contents of Fe and Al Oxides and hydroxides as a result of high degree of weathering, amount of clay minerals, drainage conditions of the soil and the degree of soil development (Udo and Dambo, 1979, Agbenin, 2003; Loganathan and Sutton, 1987).

Quantification of the various forms of P in soils is useful in estimating P availability to crops as well as the degree of weathering and soil development(Udo and Dambo, 1979; Ibia*et al* 2008). Ibia and Udo (1993) examined the influence of Parent material on the forms and distribution of P in southern Nigeria and reported that soil formed on coastal plan sands and sandstones were more weathered than those in alluvium, beach sands and shale. Udo (1985) found a wide variation in the abundance of total P in some soils derived from coastal plain sands, basaltic rocks and deltaic deposits. Also, Uzu et al (1975), Udo and Danbo (1979), Loganathan and Sutton 1987), Osodeke and Kamalu (1992)Iba and Udo (1993), Ibia et al, (2008) and Osodeke and Ubah (2006)

Observed that the relative abundance of the active inorganic P fractions decreased in the order Fe-P> Al- P > Ca – P in most soils in Nigeria.

Increases in soil productive capacity and crop yield performance require proper understanding of the soil resources and P Status in particular. The soilsofCrossRivers State are formed on a range of Parent materialsand information on P status of these soils is limited to single Parent material (Attoe and Amalu, 2005). Therefore the objectives of the study were to examine the various P forms and assess the relationship between P forms and parent materials and between P fractions and some soil properties in Cross RiverState in order to guide proper soil P management Practices in the area..

II. Materials and methods

The study was conducted in soils representative of five (5) parent materials namely coastal plain sands (Calabar), shale (Odukpani), Basement Complex Rocks (Akamkpa), sandstone (Obubra) and basaltic Rocks (Ikom), in central and southern agro-ecological zone of Cross Rivers State. The area lies between (Latitude O5^o 32^1 and O4^{o}27^{1}North and Longitude O7^o 15^1 and O9^o 28^1 South). The climate of the area is hot humid tropical and characterized by two seasons, the rainy which last from April to October and a dry period which lasts from November to March. Average rainfall amounts in this State vary from 2000 mm to 3500 mm, while temperature and relative humidity vary from 22^{o}C to 33^{o}C and 81 to 96 respectively. Soil temperature regime of the area encourages cropping throughout the year provided there is sufficient watersupply.Vegetationof the area is predominantly rainforest with extensive bush re-growth. Land use for agricultural production in the area is extensive and is the traditional low external input production systems. The major food crops grown in the state include cassava, yam, maize, cocoyam, plantain and bananas, rice and assorted vegetables. The soil locations were chosen on the basis of the land use survey report of Cross River State (Bulktrade, 1989). None of the sampled locations had any known history of previous chemical fertilizer application.

Four replicate soil samples (Approximately, 1 Kg) collected from a 50 x 50 cm dimension area at 15 cm soil depth of each parent material were used for the study. In the laboratory, the soil samples were air-dried and ground using mortar and pestle, and passed through 2- mm diameter sieve to remove materials greater than 2mm and preserved for routine soil analysis using standard methods. Particle size distribution was determined according to the procedure of Gee and Or (2002). Bulk density was determined using core sample method described by Grossman and Reinsch (2002).Soil pH was determined on a soil:Water suspension in a ratio of 1:2.5 using the P meter (Thomas 1996). Organic carbon was determined in two-gram soil sample (passed through O.5mm sieve) by the by the Walkley and Black dichromate wet Oxidation method, as outlined by Nelson and Sommers,(1996) and converted to organic matter by multiplying by a factor of 1.724. Total nitrogen was determined on samples (also passed through O.5mm diameter sieves) by the regular macroKjeldahlMethod as describedbyBremner and Malveney, (1996). Total P was extracted by the perchloric acid digestion method (Jackson, 1964) and organic P was obtained by ignition method of Legg and Black (1955). Phosphorus fractionation was done according to the method of Chang and Jackson (1957) as modified by Peterson and Corey (1966). Using O.5 m NH_4F for Al-P, 0. IM NaOH for Fe- P and 0.25M H_2SO_4 for Ca-P. Available P was extracted using Bray and Kurtz (1945) extractants (Bray P–1 and P–2) and P in the extracts was determined using the molybdenum blue colour method of Murphy and Riley (1962). From these, the active P form was obtained by summation of Al – P, Fe- P and Ca- P and occluded P form corresponding to inactive form was calculated as the difference between total. P and the sum of organic P and active P form (IMPHOS, 1989) Also, total inorganic P was obtained as the difference between total P and organic P forms.Correlation analysis was performed on the data to examine relationships between the forms of P and parent materials and forms of P and some soil properties.

III. Results and Discussion

The mean values of physical and chemical properties of the soils are presented in Table 1. Particle size analysis showed that the soils varied with the clay values, ranging from199.0 g.kg in coastal plain sands to 293.25g.kg in shale, and sand from 590.25 in sandstones to 689.5 g/kg in coastal plain sands. The soils on all parent materials were acidic with pH values ranging from 4.2 to 5.7.Theorganic carbon content ranged from 7.1 g/kg in sandstone to 13.0 g/kg in shale. Exchangeable bases were low with levels of calcium and magnesium being higher than those of potassium and sodium in the soils.

The data on phosphorus forms in relation to parent materials are shown in Table 2. The results indicated that total P values varied widely among the parent materials with mean values ranging from 76.8 mg/kg in sandstone to 290. 9mg/kg in shale. The order of relationship being shale > basaltic rocks> basement complex rocks > coastal plain sand > sandstone. The results obtained are comparable to those reported by Ibia*et al,* (2008).Thedata on available P extracted by Bray- I and 2 methods showed that Bray P – 2 extracted higher amount of phosphorus varying from mean value of 6.6 mg/kg in sandstone to mean value of 18.9 mg/kg in basaltic rocks.

Table 1. Mean Values of Physical and Chemical Properties of The Top 15cm of Soils from Varied Parent Material.

Soil Properties	Soils of Different Parent Materials				
	CPS	**SH**	**BCR**	**SS**	**BAR**
Sand (gkg^{-1})	689.5	6188.75	590.25	699.0	667.0
Silt (gkg^{-1})	111.5	88.00	147.75	99.0	98
Clay (gkg^{-1})	199.0	293.25	262.0	202.0	235.0
pH (H_2O)	5.1	57	5.3	5.2	5.6
pH (Kcl)	4.2	4.8	4.4	4.3	4.7
Org. C (gkg^{-1})	7.3	13.0	8.7	7.1	10.1
Total N (gkg^{-1})	1.2	1.7	1.3	1.1	1.6
Exch. Mg ($cmolkg^{-1}$)	2.2	2.8	2.3	2.1	2.6
Exch. Ca ($cmolkg^{-1}$)	1.3	2.5	1.6	1.4	2.2
Exch. K ($cmolkg^{-1}$)	0.10	0.24	0.15	0.13	0.21
Exch. Na ($cmolkg^{-1}$)	0.12	0.07	0.10	0.14	0.08
Exch. Al ($cmolkg^{-1}$)	2.6	1.3	1.7	1.2	1.6
Ex.Acidity($cmolkg^{-1}$)	7.7	4.3	5.7	6.4	4.9
ECEC ($cmolkg^{-1}$)	11.4	9.9	9.8	10.2	10.0
Base Sat. (%)	32.5	57.0	43.0	37.3	5.0

CPS-Coastal Plain Sand; SH-shale, BCR-basement complex rocks, SS-sandstone, BAR-basaltic rocks

Table 2. Forms of phosphorus ($mgkg^{-1}$) in the top (0 – 15cm) Soil representative parent materials

Parent Material / Location	Available P		Total P	Organic P	Active P			Total Active P	Occluded P	Total Inorganic P
	Bray 1	Bray 2			Al-P	Fe-P	Ca-P			
Coastal Plain Sand – Calabar	5.0	7.3	101.0	34.9	7.4	11.8	5.1	24.2	41.8	66.1
Shales – Odukpani	11.7	17.8	290.9	99.7	11.8	25.0	40.4	80.8	110.4	191.2
Basement Complex – Akamkpa	4.8	6.8	143.1	50.7	9.3	20.7	5.5	35.4	56.9	92.3
Sand Stones – Obubra	4.2	6.6	76.8	22.8	3.5	10.2	3.0	16.5	40.0	54.1
Basaltic Rocks – Ikom	11.0	18.9	254.5	81.3	20.7	36.1	10.4	67.1	106.2	173.3

Most of the soils had available P values less than the critical Phosphorus level for the Bray P – 1 and P – 2 of 8mg/kg and 15mg/kg respectively (Enwezor*et. al,* 1989). At low P range, Plants respond to P fertilizer application but not likely at higher levels. This results thus showed that soils derived from basaltic rocks and shale have relatively high P availability compared to soils on coastal plain sands, basement complex rocks and sandstone. The accumulation of organic P also varied widely among the soil with means values varying from 22.8 mg/kg in sandstone to 99.7mg/kg in shale and in the order sandstone < coastal plain sand < basement complex rocks < basaltic rock < shale. These results are also comparable to those reported by Loganathan and Sutton (1987) and Ibia*et al*, (2008).

The relative Proportion of the various forms of inorganic P as shown in table 2 indicated very high variability among the soils. While the total active ranged from means value of 16.5 mg/kg in sandstone to 80.8mg/kg in shale, total extractable inorganic P ranged from mean value 54.1 in sandstone to mean value of 191.2 in shale derived soils. Both active and total inorganic P are seen to have similar trend in distribution in these soils. This Pattern indicated lower values of total active and total inorganic P in soils derived from sandstone, coastal plain sand and basement complex rocks than those from basaltic rocks and shale. This would indicate that the soils of shale and basaltic rocks may have higher sorption capacity for these forms of P than those derived from coastal plain sand, basement complex rocks and sandstones Parent materials. The Fe–P dominated the active P forms in the soils in line with the reports of Ibia and Udo (1993) and Osodeke and Ubah (2006), that Fe–P are the dominant P forms in soils of Southern Nigeria. The relative abundance of the various forms of inorganic Phosphates was in the order of occluded P > Fe–P > Al–P > Ca- P (fig 1). A similar Pattern was reported by several authors (Uzu et al; 1975; Ibia and Udo, 1993; Loganathan *et al,* 1982;Osodeke and Kamali, 1992;). The high degree of chemical weathering of the soils may have resulted to the high Proportion of Occluded (inactive) and Fe–P in the soils. The low Al–P values and dominance of Occluded P (inactive) in the these soils suggest the limited capacity of the soils to supply plant available P from the inorganic forms. The active forms are generally accepted as the main source of available inorganic P for Plants (Thomas and Peaslee, 1973). Occluded P constituted between 57.7 and 74.0 Percent of total inorganic P forms in the soils. These values are comparable to the values of 30 to 84% of occluded to total inorganic P obtained by Osodeke and Kamalu, (1992).

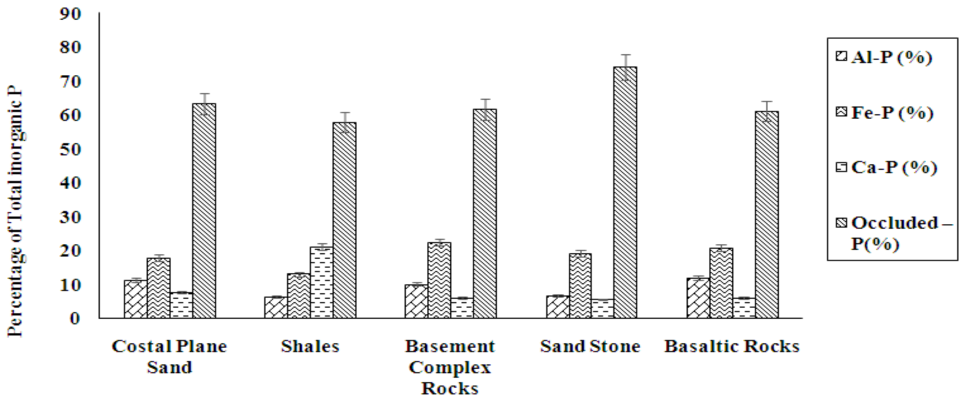

Fig 1: Mean values of Active and occluded P Forms expressed as percentage of Total inorganic P

The Phosphorus extracted by the Bray P 1 and 2 methods correlate highly and significantly with the Phosphorus fractions (Table 3) indicating that the P forms contributed more to soil available P in these soils. Being a major cation in the sorption complex, exchangeable calcium was positively and significantly correlated with total P (r = 0.507*), organic P(r = 0.580 **), thus indicating that the status of these parameters is associated with the status of calcium in these soils. The soil reaction pH also had a highly significant correlation with the P forms. The relationship between organic carbon and P forms is positive and highly significant with total-P (r = O705***), Organic-P (r = 0.635**), Al-P (r = 0.468*), Ca – P (r = 0603**), Active – p (r = 0.56***), Occluded P (r 0.616**) and inorganic P (r=0.625**). Generally P forms were strongly correlated in these soils (Table 4). Fe–P was significantly related with inorganic–P (r = 0.846***), indicating that much of the active–P was held in the sorption complex as Fe–P. There is a positive and significant relationship between organic–P and total-P (r=0.861***) Al-P with total P and organic- P(r=0.706** and r=0.781***) respectively. Fe-P had significant association with total–P, organic–P and Al–P with (r = 0.813***, r = 0.696*** and r = 0.781***) respectively (Table 4).

Table 3.: Pearson's Correlation Coefficient Between Forms Of Soil Phosphorus And Soil Properties

	Total P	Organic P	Al-P	Fe-P	Ca-P	Active .P	Occluded P	Inorganic P
Sand	-0.253	-0.236	-0.088	-0.152	-0.324	-0.196	-0.170	-0.195
Silt	-0.165	0.006	-0.152	0.069	-0.047	-0.050	-0.067	-0.058
Clay	0.392	0.281	0.187	0.146	0.306	0.262	0.240	0.266
pH	0.799***	0.915***	0.688***	0.716***	0.703***	0.837***	0.926***	0.894***
Org.C	0.705***	0.635**	0.468*	0.395	0.603**	0.596**	0.616**	0.625**
Ca	0.507*	0.580**	0.405	0.533*	0.595**	0.635**	0.625**	0.638**
Ex Al	-0.125	-0.227	-0.197	-0.079	-0.235	-0.200	-0.288	-0.239
ECEC	-0.202	-0.294	-0.209	-0.160	-0.143	-0.202	-0.292	-0.262
Bray-1-p	0.723***	0.827***	0.617**	0.636**	0.575**	0.724**	0.876***	0.819***
Bray-2-p	0.636**	0.704***	0.497*	0.572**	0.503*	0.268**	0.770***	0.714***

Level of significance: *P = 0.05, **P = 0.01, ***P = 0.001.

Table.4. Pearson's Correlation Coefficient Among Forms of Soil Phosphorus.

	Total – P	Organic - P	Al – P	Fe – P	Ca -P	Active P	Occluded - P	Inorganic P	Bray -1-P	Bray -2-P
Total – P	1.000									
Organic – P	0.861***	1.000								
Al – P	0.706***	0.662**	1.000							
Fe – P	0.813***	0.696***	0.781***	1.000						
Ca –P	0.695***	0.787***	0.444*	0.425	1.000					
Active P	0.884***	0.873***	0.820***	0.836***	0.826***	1.000				
Occluded - P	0.892***	0.951***	0.768***	0.832***	0.745***	0.934***	1.000			
Inorganic P	0.905***	0.932***	0.806***	0.846***	0.795***	0.981***	0.984***	1.000		
Bray -1-P	0.723***	0.827***	0.617**	0.636**	0.575**	0.724***	0.876***	0.819***	1.000	
Bray -2-P	0.636**	0.704***	0.497*	0.572**	0.503*	0.268**	0.770***	0.714***	0.950***	1.000

Level of significance: *P = 0.05, **P = 0.01, ***P = 0.001.

IV. Conclusion

The results showed that the distribution and status of P forms in the soils differed in relation to the parent materials. The soils derived from shale and basaltic rocks had higher levels of total P compared to those of coastal plan sand, basement complex rocks and sandstones. The various P forms correlated with plant available indices. Higher levels of available P were obtained from soil derived forms shale and basaltic rocks,whereas the values for basement complex rocks, coastal plain sand and sandstone were relatively low. Soils in this area with values of available P greater than 8mg/kg (Bray – 1) and 15 mg/kg (Bray – 2), may not require P fertilizer application for some period of farming, this justifies the necessity for soil P test to enhance proper fertilizer usage.

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