Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 11(X), 2023
http://dx.doi.org/10.7770/safer-V11N1-art2242

Forms and Profile Distribution of Phosphorus in Soils formed on different Parent Materials in different Ecologies of Edo State, Nigeria.

Formas y distribución del perfil de fósforo en suelos formados en diferentes materiales parentales en diferentes ecologías del estado de Edo, Nigeria.

Bright Ehijiele Amenkhienan*, Henry Harry Esomeme Isitekhale & Stephen Okhumata Dania
Department of Soil Science, Faculty of Agriculture, Ambrose Alli University, P.M.B 14, Ekpoma, Edo State, Nigeria.
Author for correspondence. E-mail: brightamen2004@gmail.com

ABSTRACT

Forms and profile distribution of phosphorus in soils formed on different parent materials (cretaceous sediments, shale and quaternary alluvium) in different ecologies (Ekpoma, Ozalla and Illushi) of Edo State of Nigeria were investigated. Soil samples were collected from profile pits sunk on each parent material type. Total and organic phosphorus was determined by standard laboratory procedure while inorganic phosphorus forms by fractionation. Data obtained were analyzed using t-test and correlation analysis. Results showed that the total phosphorus ranged from 402 to 650 mg kg-1, 248 to 662 mg kg-1 and 88 to 345 mg kg-1 in soils of Ekpoma, Ozalla and Illushi with means of 498, 404 and 247 mg kg-1, respectively. Ozalla soils having higher values followed by Ekpoma soils while Illushi soils have lower values. The P forms showed no definite pattern of decrease with increased soil depth except for total P that decreased with increased soil depth in all the soils. The inorganic fractions of the soils occurred in the sequence of Fe-P > Al-P > Ca-P. The inactive residual P constituted 85.91% of the total P in Ekpoma soils, while Ozalla soils and Illushi soils constituted 76.35% and 80.19% of the total P, respectively. There was a clear dominance of the inactive over the active forms of P, which partly explains the low available P in the soils and it also indicates that plants cultivated on these soils are not likely to obtain an adequate supply of P for good growth and development without P fertilizer application.

Keywords: Distribution, Ecologies, Parent materials, Phosphorus, Profile pits, Soils.

RESUMEN

Se investigaron las formas y la distribución del perfil de fósforo en suelos formados en diferentes materiales parentales (sedimentos cretáceos, lutitas y aluviones cuaternarios) en diferentes ecologías (Ekpoma, Ozalla e Illushi) del estado de Edo de Nigeria. Se recolectaron muestras de suelo de pozos de perfil hundidos en cada tipo de material parental. El fósforo total y orgánico se determinó mediante un procedimiento estándar de laboratorio, mientras que el fósforo inorgánico se forma mediante fraccionamiento. Los datos obtenidos se analizaron mediante la prueba t y análisis de correlación. Los resultados mostraron que el fósforo total osciló entre 402 a 650 mg kg-1, 248 a 662 mg kg-1 y 88 a 345 mg kg-1 en suelos de Ekpoma, Ozalla e Illushi con medias de 498, 404 y 247 mg kg- 1, respectivamente. Los suelos Ozalla tienen valores más altos seguidos por los suelos Ekpoma mientras que los suelos Illushi tienen valores más bajos. Las formas de P no mostraron un patrón definido de disminución con el aumento de la profundidad del suelo, excepto por el P total que disminuyó con el aumento de la profundidad del suelo en todos los suelos. Las fracciones inorgánicas de los suelos ocurrieron en la secuencia de Fe-P> Al-P> Ca-P. El P residual inactivo constituyó el 85,91% del P total en los suelos Ekpoma, mientras que los suelos Ozalla y los suelos Illushi constituyeron el 76,35% y el 80,19% del P total, respectivamente. Hubo un claro predominio de las formas inactivas sobre las activas de P, lo que explica en parte el bajo P disponible en los suelos y también indica que las plantas cultivadas en estos suelos probablemente no obtendrán un suministro adecuado de P para un buen crecimiento y desarrollo. sin aplicación de fertilizante fosfatado.

Palabras clave: Distribución, Ecologías, Materiales parentales, Fósforo, Perfiles de hoyos, Suelos.

INTRODUCTION

Phosphorus (P) is a basic supplement required by plants and it is second in significance to nitrogen (N) for expanded harvest creation in most tropical soils. The assurance of P is a significant factor to be considered in assessing soil richness. The relative dissemination and amount of different types of P are of extraordinary core to pedogenetic advancement of soil and studies of fertility (Amhakhian and Osemwota, 2012). The regular source of P in many soils are little and their accessibility to which is available is low. The total P content in many soils can be enormous and just a little portion is accessible or in a natural structure for organic use since it is limited either to partly weathered mineral particles, adsorbed on mineral surfaces or over the time of soil development, made available by formation of secondary mineral. (Yang *et al*, 2013). At times, it is precipitated by dissolved Al or Fe at low pH. Using the soil P reserves for sustainable crop production the forms and distribution of P in agricultural soils may show procedures and potential outcomes of soil P (Ulen and Snall, 2007).

P exists in soil in two major forms: organic and inorganic forms (Busman *et al.,* 2002; Agbede, 2009). The P in organic forms originates from humus and other organic materials and with the involvement of microorganisms in soil acting on the humus and organic materials, P is released into the soil through mineralization processes while the phosphorus in inorganic forms occurs as calcium phosphate (Ca-P), Aluminium phosphate (Al-P), iron phosphate (Fe-P), reductant soluble phosphate (Red-P) Saloid-bound phosphate (Sal-P), and occluded phosphate (Occ-P) (Westing and De-Brito, 1969).

Some of the factors influencing against relevant understanding of P behaviors in soil are, the major differences between crops in their capacity to take up different forms of P, numerous inorganic and organic forms of P that occur in soils as well as the wider variation in behavior between soil types (Ohaeri and Eshett, 2011).

Studying the forms and distribution of various forms of P in soil provides valuable information in evaluating the status of available P and measuring the level of soil weathering (Ohaeri and Eshett, 2011). The forms and distribution of the active inorganic form of P (Fe-P, Al–P and Ca–P) in the soil is valuable in order to assess the requirement of P by crops and its availability in soil are dependent on pH, the solubility product of the different phosphate, parent materials, cations present and the level of weathering (Kleinman *et al*, 1999). Quantification of organic P is essential to understanding the mineralization-immobilization turnover of P under specific locations and cropping systems in the soils (Ohaeri and Eshett, 2011). Adequate information of total P, available P and various fractions of P of some important agricultural soils of different ecologies of Edo State, Nigeria, as well as, their distribution and availability to crops, is important in management of P in these soils, level of fertilizer to be applied to crops and fertilizer recommendation.

Hence, the aim of this study is to evaluate the forms of P, the pattern of their distribution with profile depth, as well as the factors influencing their distribution in different ecologies of Edo State.

MATERIALS AND METHODS

Study Area: The study area covered three different ecologies based on soils formed on three different parent materials in Edo State namely, Ekpoma, Ozalla and Illushi. Ekpoma, Ozalla and Illushi represent parent materials of cretaceous sediments, shale and quaternary alluvium.

Ekpoma geographical coordinates is latitude 6° 45'N and longitude 6° 08'E. The vegetation is a transition zone between rainforest zone and savannah zone. 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 an agrarian town. Ekpoma soil is derived from coastal plain sand (EADP, 1995).

Ozalla geographical coordinates is between latitude 6° 48′N, and longitude 6° 01′E. The vegetation is rainforest forest zone. The wet season occurs between April and October with short break in August while the dry season last from November to March. It is also an agrarian town (EADP, 1995).

Illushi lies between latitudes 06° 40′N and longitudes 06° 37′E. On the eastern side of this site is River Niger, which seasonally overflows its bank to flood the land while it is bounded southwards by Oria community. While in some years, rains may commence as early as April, in some others it is as late as July. Flooding pattern is equally as unpredictable as the rainfall. It is seasonally flooded from the River Niger resulting in the alluvial deposits from which the soils are largely derived. The distribution pattern of rainfall is such that the area can be without rain for as long as 5–6 months (November – April). Vegetation is guinea savannah characterized by numerous grass species and scattered shrubs. It is an agrarian community (Umweni and Ogunkunle, 2014).

Field Studies: In the field, three profile pits measuring 1.5 m x 1.4 m (2 m depth) were dug in each location. Horizons were delineated according to colour in accordance to Anderson and Ingram (1993) and Okalebo *et al.* (2002). Soil samples were collected starting from the bottom horizon to the top horizon into properly labelled soil bag. The soil samples were air dried at room temperature for a week, then crushed and passed through 2 mm sieve in readiness for laboratory analysis.

Laboratory Analysis: The hydrometer method was used to determine particle size distribution (Okalebo *et al*., 2002). Glass electrode pH meter in 1:1 (soil: water) was used to determine pH of the soil (MaClean, 1982). The methods of Udo *et al.* (2009) was used to determined organic carbon. Bray P-1 solution was used to extract available P and was determined through the molybdenum blue method on the technician auto-analyzer (Olsen and Sommers, 1982). The exchangeable cations (calcium, magnesium and potassium) was extracted with 1N ammonium acetate at pH 7.0. The flame emission photometer was used to determine potassium (K) while atomic adsorption spectrophotometer was used to determine calcium (Ca) and magnesium (Mg) (Anderson and Ingram, 1993). Summation of exchangeable bases and exchangeable acidity gave the effective cation exchange capacity (ECEC). Perchloric acid digestion method was used to determine total P (Murphy and Riley, 1962) while ignition method was used to determine the organic P (Legg and Black, 1955). The fractionation method of Chang and Jackson (1957) modified by Peterson and Corey (1966) was used to determine inorganic P. The forms determined were; Ca-P, Al-P, Fe-P, saloid-bound P and occluded Fe- and Al-P. Saloid-Bound P: 1g of soil was placed in 100ml centrifuge tube, 500ml of 1N NH_4Cl was added, shaken for 30 minutes, the suspension was centrifuged at 2000rpm for 10 minutes, decanted and the supernatant liquid was stored for P determination. Al-P: 50ml of 0.5N NH_4F at pH 8.2 was added to the residue from I, it was shaken for 1 hour, centrifuged and the supernatant kept for P determination. Fe-P: the soil residue of the above was washed once with 35ml saturated NaCl, centrifuged at 2000rpm for 5 minutes, decanted. 50ml of 0.1N NaOH was added, shaken and centrifuge for 15minutes at 2400rpm, it was decanted and the supernatant liquid kept in a 50ml conical flask. 5 drops of concentrated H_2SO_4 was added to the supernatant in a 50ml conical flask and the flask swirled to flocculate the organic matter. More H_2SO_4 was added when solution was still coloured. If colour was still not removed, it was filtered through P-free charcoal and P in the supernatant determined. Occluded Fe-and Al-P: the soil residue was washed with 25ml NaCl, 50ml of 0.01N NaOH added and shaken overnight, the suspension was centrifuged for 15 minutes at 2400rpm, the colour was removed from the suspension with concentrated H_2SO_4, and the P in the supernatant was determined. Ca-P: the soil residue was washed with 25ml NaCl, 50ml of 0.25N H_2SO_4 was added, shaken for 1 hour and centrifuged for 10 minutes at 2000rpm then P in the supernatant was determined. The residual P was taken as the differences between total P and inorganic and organic P (Udo, 1981).

Statistical Analysis: All data obtained were statistically analyzed using t-test to test the differences between means and were also correlated to show the statistical relationship between important pedological characteristics (SAS, 2005).

RESULTS AND DISCUSSION

Forms and Distribution of P: The results of the P distribution in the soils formed on the three different parent materials are shown in Table 1.

Available Phosphorus: Available P ranged from 4.45 to 8.71 mg kg-1, 6.72 to 33.66 mg kg-1 and 6.01 to 9.00 mg kg-1 in soils formed on cretaceous sediment, shale and quaternary alluvium parent materials, respectively. It increased with depth in soils formed on quaternary alluvium while it decreased in soils formed on cretaceous sediment and shale. The available P concentration in soils formed on cretaceous sediment and quaternary alluvium was low, but highest P (33.66 mg kg-1) was recorded on surface soils of shale and it was above the critical level of 15 mg kg-1 (Agboola and Corey, 1972) established for southern Nigerian soils. In this study, the low P concentration of the soils formed on cretaceous sediment and quaternary alluvium could be due to the high soil acidity. This agrees with the findings of Uzoho and Oti (2004); Adegbenro *et al.* (2011) who attributed the low P content to the pH status of the soil and also to the fixation of P by Fe and Al sesquioxides.

Total Phosphorus: Total P ranged from 402 to 650 mg kg-1, 248 to 662 mg kg-1 and 88 to 345 mg kg-1 in soils formed on cretaceous sediment, shale and quaternary alluvium, respectively.. Total P of the soils tended to decrease with depth in soils formed on the different parent materials. The top soils (0-15 cm) of the soils formed on the different parent materials had the highest total P concentration possibly due to high level of organic matter content. The soils of Ozalla, derived from shale, contain the highest amount of total P (662 mg kg-1) followed by soils of Ekpoma derived from cretaceous sediments (650 mg kg-1). This is in agreement with the report of Ohaeri and Eshett (2011) who found out that soil derived from shale contains the highest amount of total P (1252 mg kg-1) followed by soil derived from cretaceous sediments (301 mg kg-1). The high total P in soils of cretaceous sediments and shale reflects the high content of phosphate of the parent rock from which the soils were formed (Akamigbo and Asadu, 1983). The total P concentration obtained in soils of quaternary alluvium were low when compared to the values of 418.70 to 763.10 mg kg-1 found by Adegbenro *et al.* (2011) in soil of the Mica schist, 217 to 638 mg kg-1 obtained by Uzu *et al*. (1975) in soil of the basement complex and 191 to 243 mg kg-1 revealed by Loganathan and Sutton (1987) in soil of cretaceous sediments. The low total P concentration level could be attributed to the pH status of the soils and the presence of hydrous metal oxides of Fe and Al and clay.

Organic Phosphorus: Organic P of the soils ranged from 8.65 to 19.19 mg kg-1, 10.92 to 37.86 mg kg-1 and 10.21 to 13.56 mg kg-1 in cretaceous sediment, shale and quaternary alluvium, respectively. Generally, values obtained from the organic P were low in soils of the three parent materials. These values obtained from the organic P when compared with the values (34 to 339 mg kg-1 and 30 to 900 mg kg-1) reported by Loganathan and Sutton (1987) in the Coastal Plain Sands and the values reported by Uzu *et al.,* (1975) in the soils of Southeastern Nigeria are lower, but the values are comparable with the values (1.0 to 90 mg kg-1 and 28.88 to 88 mg kg-1) reported by Lognathan *et al.* (1982), and Osodeke and Kamalu (1992). The low level of organic P of these soils reflects their low level of organic matter content. In cretaceous sediment, organic P constituted 2.34% of the total P, soils formed on shale and quaternary alluvium constituted 4.39% and 4.68% of the total P, respectively.

Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 11(X), 2023
http://dx.doi.org/10.7770/safer-V11N1-art2242

Table 1. Forms of Phosphorus in soils formed on the three different parent materials

Location	Depth (cm)	Parent Materials	Saloid P	Al-P	Fe-P	Ca-P	Organic P	Occluded P	Occluded Fe &Al-P	Residual P	Total P	Av. P
			←				Mg kg-1					→
Ekpoma	0-15	Cretaceous Sediments	2.44	15.07	28.98	4.34	19.19	4.80	16.03	582.42	650	8.71
	15-56		2.56	18.38	37.33	4.22	10.43	8.79	7.08	407.64	478	6.23
	56-115		5.59	39.95	51.44	3.54	8.65	7.06	6.93	374.72	478	4.45
	115-144		8.50	13.97	39.76	5.14	9.86	14.92	9.39	411.27	480	5.66
	144-200		1.86	24.63	34.42	7.99	10.17	9.99	14.31	324.79	402	5.87
	Mean		4.19	22.40	38.39	5.05	11.66	9.11	10.75	420.17	498	6.18
	S.D		±2.81	±10.65	±8.33	±1.74	±4.26	±3.79	±4.20	± 97.11	±0.91	±1.56
	C.V(%)		67.04	47.54	21.70	34.46	36.54	41.60	39.07	24.15	18.27	25.24
Ozalla		Shale										
	0-5		2.33	20.30	93.90	7.76	37.86	6.78	10.83	499.85	662	33.66
	5-14		1.63	12.50	45.98	4.79	21.09	9.60	14.18	354.01	440	16.89
	14-31		1.28	13.87	83.92	4.91	13.41	12.26	2.46	284.61	402	9.21
	31-55		8.26	7.84	90.08	5.16	10.92	8.54	13.45	262.74	385	9.64
	55-80		3.96	2.70	20.33	3.62	11.38	7.35	8.50	242.01	284	6.72
	80-200		3.33	2.92	20.02	4.98	11.63	7.48	8.54	205.12	248	7.08
	Mean		3.46	10.02	59.04	5.20	17.72	8.67	9.66	308.06	404	13.87
	S.D		±2.56	±6.86	±34.61	±1.37	±10.57	±2.03	±4.26	± 106.26	±1.46	±10.37
	C.V(%)		73.98	68.46	58.62	26.35	59.65	23.41	44.09	34.49	36.14	74.77
Illushi		Quaternary Alluvium										
	0-10		3.52	2.27	20.44	4.62	10.21	7.68	7.48	312.94	354	7.43
	10-24		2.46	1.85	18.80	4.36	10.37	6.66	8.72	250.16	288	6.01
	24-52		2.60	1.45	16.88	4.42	11.50	5.85	9.45	249.15	286	6.15
	52-71		5.52	3.25	22.34	3.56	11.35	8.82	7.68	155.98	202	7.28
	71-90		1.98	1.26	60.39	5.16	13.56	6.78	7.66	205.65	288	7.15
	90-99		2.86	1.22	34.88	3.54	13.20	9.58	6.45	165.30	221	8.36
	99-200		3.45	2.12	20.55	5.63	10.55	7.25	4.88	45.70	88	9.00
	Mean		3.20	1.92	27.75	4.47	11.53	7.52	7.47	197.84	247	13.87
	S.D		±1.16	±0.72	±7.59	±0.77	±1.35	±1.30	±1.49	± 86.25	±0.86	±10.37
	C.V(%)		36.25	37.50	27.35	17.23	11.71	17.29	19.95	45.60	34.82	74.77

Inorganic Phosphorus Fractions: The distributions of the various forms of inorganic P in the soils are shown in Table 1. The Al-P content of the soils ranged from 13.97 to 39.95 mg kg-1, 2.70 to 20.30 mg kg-1 and 1.22 to 3.25 mg kg-1 in cretaceous sediment, shale and quaternary alluvium,, respectively. The content of Al-P was low in soils derived from the parent materials studied and this is a reflection of the fact that Al-P fraction, which controls the plant available phosphorus in acidic soils, had been depleted severely in the area of study. Saloid P (part of the total active P) was generally low in the parent materials. It ranged from 1.86 to 8.50 mg kg-1, 1.23 to 8.26 mg kg-1 and 1.98 to 5.52 mg kg-1 in soils formed on cretaceous sediments, shale and quaternary alluvium, respectively.

The content of Fe-P was higher than that of the content of Al-P among the soils derived on the three different parent materials. Fe-P ranged from 28.98 to 51.44 mg kg-1, 20.02 to 93.90 mg kg-1 and 16.88 to 60.39 mg kg-1 in soils formed on cretaceous sediment, shale and quaternary alluvium, respectively. The high quantity of Fe-P of all the other fractions is anticipated since the soils were basically very strongly to strongly acidic and possibly due to the abundant Fe presence in soils formed on the parent materials. This high Fe-P relative to other forms of P was also reported by Adegbenro *et al*. (2011). The abundance of Fe-P among the active inorganic P was in line with the report of Asmare *et al*. (2015) as this was as a result of high oxides of iron content, low pH status, and advanced level of weathering.

The Ca-P content ranged from 3.54 to 7.99 mg kg-1, 3.62 to 7.76 mg kg-1 and 3.54 to 5.63 mg kg-1 in soils formed on cretaceous sediment, shale and quaternary alluvium, respectively. Generally, Ca-P was low in soils formed on the parent materials. The low quantity of Ca-P found in the studied soils may be due to the probable changes of Al-P and Fe-P in the acidic to slightly matured soils. In acid soils, the Al-P and Fe-P are significant but in alkaline and calcareous soils, Ca-P assumes the most significant roles (Omoregie and Oshineye, 1998). According to Omoregie and Aken'Ova, (1999) the low content of Ca-P indicates higher degree of weathering of the soils. However, inorganic soil P fraction tends to increase with the degree weathering. The amount of P linked to Al, Fe, and Ca was directly related to the intensity of weathering in that when Al and Fe fraction dominated the soil system, the soil becomes weathered extremely and vice versa. On the Chang and Jackson (1958) scale, "the observed distributions of the inorganic P forms indicated that all the soils were moderately weathered and are capable of fixing reasonable proportion of the existing small amounts of the native soil phosphorus in relatively unavailable form".

The Occluded Fe and Al-P concentration ranged from 6.93 to 16.03, 2.46 to 14.18 mg kg-1 and 4.48 to 9.45 mg kg-1 in soils formed on cretaceous sediments, shale and quaternary alluvium, respectively. It contributed very little to total P. Occluded P concentration ranged from 4.80 to 14.92 mg kg-1, 6.78 to 12.26 mg kg-1 and 5.85 to 9.58 mg kg-1 in soils formed on cretaceous sediments, shale and quaternary alluvium, respectively. It was also very low. The total inorganic P comprises active and inactive forms, where the active form consists of Al-P, Fe-P and Ca-P while the inactive form consists of occluded and residual P (Chang and Jackson, 1957; Omoregie and Aken'Ova, 1999). The active P constituted 14.07%,,19.26% 15.13% of the total P in soils formed on cretaceous sediments, shale and quaternary alluvium respectively while inactive residual P constituted 85.91%, 76.35% and 80.19% of the total P in soils formed on cretaceous sediments, shale and quaternary alluvium ,respectively. This means that most of the soil P were in unavailable form which the plants cannot use.

Mean Comparison of the Forms of Phosphorus using t-test: The mean comparison of the forms of P using t-test is shown in Table 2. Comparison of soils formed on cretaceous sediment and shale showed that Al-P and total P were higher significantly in cretaceous sediment while Fe-P and organic-P were higher significantly in soils formed on shale. However, there were no significant differences ($P \leq 0.05$) in saloid P, occluded P, occluded Fe & Al-P and Ca-P. Between soils formed on quaternary alluvium and cretaceous sediment; Al-P, Fe-P, occluded P, occluded Fe & Al-P, Ca-P were higher significantly in soils formed on cretaceous sediment while saloid P was higher in soils formed on shale. There was no significant difference ($P \leq 0.05$) in organic P and total P in soils derived on both parent materials. Comparison of soils formed on shale and quaternary alluvium reveals that all the forms of P were higher significantly in soils formed on shale except for saloid P that was not significantly different.

Correlation coefficient (relationship) among Forms of Phosphorus in Soils Formed on the three Parent Materials: The correlation coefficient of the forms of P in soils formed on the cretaceous sediments is presented in Table 3. Fe-P was negatively and significantly correlated with the available P (r = -0.882*), while the total P had a positive and significant correlation with the organic P (r = 0.901*), moreover organic P was positively and significantly correlated with available P (r = 0.960**). This was in agreement with Agboola and Ayodele (1983); Akinrinde and Obigbesan (2000); and Aduloju and Abdulmumini (2014) reporting that in soils of the tropics, the organic P is significantly determinant of the P availability. Similar results have also been reported by Ohaeri and Eshett (2011) that total P correlated positively with organic P which is a significant determinant of P availability in soils. In an Alfisol of Sri Lankan, Morris *et al.* (1992) observed a positive relationship between organic P and P uptake by millet. Brady and Weil (2002) also observed that in the mineralization and uptake of P by plants, organic P is indeed important.

Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 11(X), 2023
http://dx.doi.org/10.7770/safer-V11N1-art2242

Table 2. Mean comparison of the forms of phosphorus in soils formed on the three parent materials

Location	Parent Materials		Saloid P	Al-P	Fe-P	Ca-P	Organic P	Occluded P	Occluded Fe & Al-P	Total P
			Mg kg-1							
Ekpoma	Cretaceous Sediments	Mean	4.19	22.40	38.39	5.05	11.66	9.11	10.75	4.98
		CV(%)	67.04	47.54	21.70	34.46	36.54	41.60	39.07	18.27
Ozalla	Shale	Mean	3.46	10.02	59.04	5.20	17.72	8.67	9.66	4.04
		CV(%)	73.98	68.46	58.62	26.35	59.65	23.41	44.09	36.14
t-test: Ekpoma and Ozalla			NS	*	*	NS	*	NS	NS	*
Illushi	Quaternary Alluvium	Mean	3.20	1.92	27.75	4.47	11.53	7.52	7.47	2.47
		CV(%)	36.25	37.50	27.35	17.23	11.71	17.29	19.95	34.82
t-test: Ozalla and Illushi			NS	*	*	*	*	*	*	*
t-test: Illushi and Ekpoma	Quaternary Alluvium		*	*	*	*	NS	*	*	NS

*: Significant at 5% level
NS: Not Significant

Table 3. Correlation coefficient of forms of phosphorus in soil formed on cretaceous sediments

	Al-P	Fe-P	Ca-P	Occluded P	Occluded Fe & Al-P	Total P	Organic P	Available P
Saloid P	0.020	0.550	-0.305	0.661	-0.482	-0.112	-0.410	-0.480
Al-P		0.794	-0.164	-0.310	-0.400	-0.371	-0.502	-0.682
Fe-P			-0.408	0.147	-0.798	-0.431	-0.742	-0.882*
Ca-P				0.361	0.527	-0.542	-0.146	-0.017
Occluded P					-0.291	-0.575	-0.583	-0.451
Occluded Fe & Al-P						0.414	0.739	0.739
Total P							0.901*	0.800
Organic P								0.960**

* : Significant at 5% level
**: Significant at 1% level

In soils formed on shale parent material, Al-P was significantly and positively correlated with total P, organic P and available P (r = 0.949**, r = 0.836* and r = 0.851*, respectively) (Table 4). Ca-P had a positive and significant correlation with total P (r = 0.871*) organic P (r = 0.872*) and available P (r = 0.899*). Total P correlated significantly and positively with organic P (r = 0.927**) and available P (r = 0.952**). Organic P was found to have a positive and significant correlation with the available P (r = 0.993**) (Table 4).

Table 4. Correlation coefficient of forms of phosphorus in soil formed on shale

	Al-P	Fe-P	Ca-P	Occluded P	Occluded Fe & Al-P	Total P	Organic P	Available P
Saloid P	-0.430	0.147	-0.141	-0.317	0.438	-0.259	-0.404	-0.307
Al-P		0.770	0.797	0.217	0.025	0.949**	0.836*	0.851*
Fe-P			0.659	0.299	0.012	0.736	0.450	0.527
Ca-P				-0.282	0.177	0.871*	0.872*	0.899*
Occluded P					-0.499	-0.078	-0.317	-0.317
Occluded Fe & Al-P						0.232	0.259	0.318
Total P							0.927**	0.952**
Organic P								0.993**

* : Significant at 5% level
**: Significant at 1% level

In soils formed on quaternary alluvium, saloid P was positively and significantly correlated with Al-P with ‘r’ value of 0.928** (Table 5). In addition, a significant and positive correlation was found between Fe-P and organic P (r = 0.844**). Occluded Fe and Al-P had a negative and significant correlation with the available P (r = -0.972**).

As conclusion, the result of the forms of phosphorus indicated that the pattern of their distribution with depth was not uniform in all of the studied soils in the different ecologies. The relative abundance of various forms of inorganic phosphorus were in the sequence of Fe-

P > Al-P > Ca-P. The inactive residual P constituted 85.91% of the total phosphorus in soils formed on cretaceous sediments, while constituted a 76.35% and a 80.19% of the total P in soils formed on shale and quaternary alluvium,, respectively. This means that most of the soil P were as unavailable form, which the plants cannot use. Therefore the soil of the different ecologies will need phosphorus fertilization for cropping in order to attain fertilizer best practice for production of crops.

Table 5. Correlation coefficient of forms of phosphorus in soil formed on quaternary alluvium

	Al-P	Fe-P	Ca-P	Occluded P	Occluded Fe & Al-P	Total P	Organic P	Available P
Saloid P	0.928**	-0.424	-0.409	0.536	-0.208	-0.343	-0.346	0.251
Al-P		-0.479	-0.211	0.291	-0.104	-0.228	-0.569	0.075
Fe-P			0.180	0.084	-0.118	0.121	0.844**	0.135
Ca-P				-0.621	-0.342	-0.205	-0.191	0.224
Occluded P					-0.487	-0.273	0.266	0.577
Occluded Fe & Al-P						0.737	-0.028	-0.972**
Total P							0.020	-0.693
Organic P								0.132

* : Significant at 5% level
**: Significant at 1% level

It could be concluded therefore, that the status of the total phosphorus as well as the various forms they exist in the studied soils in the different ecologies depend upon the type of different parent materials from which these soils were formed. Therefore, parent materials have very significant influence on the overlaying soils when the soil is formed in-situ from parent material.

References

Adegbenro, R.O.; Ojetade, J.O.; and Amusan A.A., 2011. Effect of Topography on Phosphorus Forms and Distribution in Soils Formed in Mica Schist in Ife Area. *Journal of Agriculture and Veterinary Sciences* 5: 86-105.

Aduloju, M.O. and Abdulmumini, A.A., 2014. Distribution of organic and available forms of phosphorous and micronutrients in the soils of a toposequence in Mokwa, Niger State, Nigeria. *International Journal of Development and Sustainability* 3:268-275.

Agbede, O.O., 2009. *Understanding soil and plant nutrition*. Petra Digital Press, Nigeria.167-180.

Agboola, A. A. and Corey, R. B., 1976. Nutrient deficiency survey of maize in Western Nigeria. *Nigerian Journal of Science* 10: 1-13.

Agboola, A. A. and Ayodele, O. J., 1983. An attempt to evaluate plant available P in western Nigeria savanna soils under traditional fallow systems. 3rd International Conference on Phosphorous compounds. *Brussels*, 261-287.

Akamigbo, F.O.R. and Asadu, C.L.A., 1983. Influence of parent materials on soils of southeastern Nigeria. *East African Forestry Journal*, 48:81-91.

Akinrinde, E. A. and Obigbesan, G. O., 2000. Evaluation of the fertility status of selected soils for crop production in five ecological zones of Nigeria. Proceedings of the 26th Annual Conference of the Soil Science Society of Nigeria, University of Ibadan, Ibadan, Nigeria. 30th Oct.-3rd Nov. 2000, 279-288.

Amhakhian, S.O. and Osemwota, I.O., 2012. Characterization of phosphorus status in soils of the Guinea savanna zone of Nigeria. *Nigerian Journal of Soil Science* 22:37-43.

Anderson, J.M. and Ingram, J.S., 1993. Tropical soil biology and fertility. *A handbook of methods*. Information and Press Eynsham.

Asmare, M.; Heluf, G.; Markku, Y. and Birru, Y., 2015. Phosphorus Status, Inorganic Phosphorus Forms, and Other Physicochemical Properties of Acid Soils of Farta District, Northwestern Highlands of Ethiopia. *Applied and Environmental Soil Science*, 11pp.

Brady, N.C. and Weil, R.R., 2002. *The Nature and Properties of Soils*, 13th Edition. Macmillan, New York, 683pp.

Bremner, J.M., 1982. Inorganic nitrogen. In: Page, A.L.; Miller, R.H. and Keeney, D.R. (eds.) *Methods of Soil Analysis,* Part 2. Second Edition. American Society of Agronomy, Madison, Wiscousin USA.

Busman, L.; Lamb, J.; Randall, G.; Rehm, G. and Schmitt, M., 2002. The nature of phosphorus in soils. University of Minnesota Extension Service, Available at *http://www.extension.umn.edu/distributution/cropsystems/DC6795.html.*

Chang, S.C and Jackson, M.L. (1957). Fractionation of Phosphrous. *Soil Science* 84: 133-144.

Chang, S.C and Jackson, M.L., 1958. Soil phosphorus fractions in some representative soils. *Journal of Soil Science* 84: 133-144.

EADP (Edo State Agricultural Development Project), 1995. *Edo State Agricultural Development Project Annual Report*. 1995.

Kleinman, P.J.A; Bryant, R.B. and Rad, W.S., 1999. Development of Pedotransfer Functions to quantity Phosphorus Saturation of Agricultural Soil. *Journal of Environmental Quality* 28:2026-2030.

Legg, J.O. and Black, C.A., 1955. Determination of organic phosphorus in soils II: Ignition method. *Soil Science Society of America Proceedings* 19: 139-142.

Loganathan P., Dayaratne, M.N. and Shanmuganathan, 1982. Evaluation of the phosphorus status of some coconut growing soils of Sri Lanka. *Journal Agricultural Science.* 99: 25 – 33.

Lognanathan, P. and Sutton, P. M., 1987. Phosphorus fractions and availability in soils formed on different geological deposits in the Niger Area of Nigeria. *Journal of Soil Science* 143: 16-25.

MaClean, E.O., 1982. Soil pH and lime requirement in Black, C.A. (Ed): *Methods in soil analysis chemical and microbiological properties* Part II-American Society of Agronomy, Madison, Wiscousin USA, 927-932.

Morris, R. A., Sattell, R. R. and Christensen, N. W., 1992. Phosphorous sorption and uptake from Sri Lankan Alfisols. *Soil Science*, 56:1516-1520.

Murphy, J. and Riley, J.P., 1962. A modified single solution method for the determination of phosphorus in natural water. *Analytical Chemical. ACTA* 27:31-36.

Ohaeri, J. E. and Eshett, E. T., 2011. Phosphorus forms and distribution in selected soils formed over different parent materials in Abia State of Nigeria. *Agro Science* 10:28-37.

Okalebo, J.R.; Gathua, K.W and Woomer, P.L., 2002. Laboratory methods of soil and plant analysis. *A working manual.* 2nd edition. Sacred Africa, Nairobi, Kenya, 22-77.

Olsen, G.J. and Sommers, L.E., 1982. Phosphorus in Page A.L.; Miller R.H. and Keeney, D.R. (eds.) *Methods of Soil Analysis,* Part 2. Second Edition. American Society of Agronomy, Madison, Wiscousin, USA, 402-403.

Omoregie, A.U. and Oshineye, A.A. (1998). Forms, distribution and availability of phosphorus in some soils supporting natural forages in the derived savanna of Nigeria. *Thai Journal of Agricultural Science* 31:533-542.

Omoregie, A.U. and Aken'Ova, M.E., 1999. Phosphorus status and sorption capacities of some native rangeland soils in northern Nigeria. *Tropical Agricultural Research and Extension* 2:101-106.

Osodeke, V. E. and Kamalu, O. J., 1992. Phosphorus status of Hevea growing soils of Nigeria. *Indian Journal of natural Rubber Research* 5:107-112.

Peterson, G.W. and Corey, R.B., 1966. A modified Chang and Jackson procedure for routine fractionation of inorganic soil phosphates. *Soil Science Society of America Journal* 30:563-565.

SAS, 2005. SAS user guide. *Statistical Analysis System Institute*. Cary. North California, USA, 957pp.

Sobulo, R. A. and Osiname, O. A., 1981. Soils and fertilizer use in Western Nigeria. *Research Bulletin* No 11, I.A.R.T. Ibadan, PP 20 – 26.

Thomas, G. W., 1982. Exchangeable cation. In page, A. L. *et al* (eds) methods of soil analysis. Part 2, *Agronomy monograph*, a second edition, 165pp. American Society of Agronomy and Soil Science Society America, Madison, Wiscosin, USA.

Udo, E. J., 1981. Phosphorus forms, adsorption and desorption in selected Nigerian soils. *Nigerian Journal of Science* 2: 51 – 66.

Udo, E. J., Ibia, T. O., Ogunwale, J. A., Anuo, A. O. and Esu, I. E., 2009. Manual of soil, plant and water analysis. Sibon books Ltd, Lagos, Nigeria.

Ulen, B. and Snall, S., 2007. Forms and retention of phosphorus in an illite-clay soil profile with a history of fertilization with pig manure and mineral fertilizers. *Geoderma* 137: 455-465.

Umweni, A.S. and Ogunkunle, A.O., 2014. Irrigation Capability Evaluation of Illushi Floodplain, Edo State, Nigeria. *International Soil and Water Conservation Research* 2:79-87.

Uzoho, B.U. and Oti, N.N., 2004. Phosphorus Absorption Characteristics of Selected Southwestern Nigeria Soils. *Proceedings of the 29th Annual Conference of the Soil Science Society of Nigeria, Abeokuta, Nigeria* 121-130.

Uzu, F. O., Juo, A. S. R. and Fayemi, A. A., 1975. Forms of phosphorus in some important agricultural soils of Nigeria. *Soil Science* 120: 212-218.

Westing, F.C. and De-Brito, J.G., 1969. Phosphorus fractions in some Venezuelan soils as related to their stage of weathering. *Soil Science* 37:29-38.

Yang, X., Post, W. M., Thornton, P. E and Jain, A., 2013. The distribution of soil phosphorus for global biogeochemical modelling. *Bio geosciences* 10: 2525-2537.

Received: 24th June 2020; Accepted: 12th March 2021; First distribution: