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Variability and Distribution of Phosphorus Fractions under Different Land Use Types in Federal University of Agriculture, Abeokuta Ogun State, Nigeria.

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ABSTRACT.

Soil phosphorus (P) is an important macro nutrient which is required for growth and development of plants in the forest ecosystem. Its quantity in the soil influences the soil nutrient status. The study investigated the bio-availability of these essential element (phosphorus) fractions under five different land use practices. The study was a 3 × 5 factorial experiments laid out in a Completely Randomized Design. Soil samples were collected from the selected five land use practices (LUPs) including *Tectona grandis*, *Gmelina arborea*, *Leucaena leucocephala*, fallow land and secondary forest at three soil depths (0-30 cm, 30-60 cm and 60-90 cm). Samples were analyzed for Phosphorus fractions; calcium phosphate (Ca-P), aluminum phosphate (Al-P), iron phosphate (Fe-P), available phosphorus (AV-P) and total phosphorus (T-P) following standard laboratory procedures. Data obtained were subjected to Analysis of Variance. The Result showed that there was variability in the distribution of P fraction in the selected study location. Highest Ca-P (10.20±0.01), Fe-P (4.80±0.01) Total-P and (112.12±0.32) were recorded at 0-30 cm depth while Av-P (8.48±0.01) had highest values at 60-90 cm depth, Highest Ca-P (10.02±0.01mg/kg), Av-P (0.95±0.00 mg/kg) and Total-P (112.12±0.16mg/kg) were recorded for *Leucaena leucocephala*. Highest Al-P (8.53±0.32mg/kg) were recorded in Secondary Forest and least Av-P (4.21±0.02mg/kg) were recorded for *Gmelina arborea*. Lowest Fe-P (3.19±0.01mg/kg) and Ca-P (2.15±0.02mg/kg) were obtained in *Tectona grandis*. The least Al-P (5.2±0.0.15mg/kg) and Total-P (72.62±0.39mg/kg) were observed in fallow land. The study showed spatial variation among land use practices in the study locations.

Keywords: Phosphorus, environmental, practices, physiochemical, fallow land, forest.

Introduction

Phosphorus (P) is one the major and important sources of nutrients determining the function and primary productivity of terrestrial ecosystems (Elser *et al.*, 2007). It has a chemical symbol of P with atomic number 15. Some soils experienced very low capacity to supply sufficient phosphorus (P) for crop production. Meanwhile, P is an essential nutrient for plant growth and development. It stimulates growth of young plants, giving them a good and vigorous start. Phosphorus stress early in the growing season will reduce crop productivity more than P restrictions later in the crop cycle (Grant and Flaten, 2019). Absence or inadequate volumes of the phosphorus, plants fail to get off to a quick start, their root systems do not develop satisfactorily, the plants become dwarfed, and they tend to show a purplish discoloration of the stems and of the petioles and lower sides of the leaves (Mengel *et al.*, 2001).

Phosphorus is Crucial component of soil nutrients. It sustains agricultural output and its deficiency reduces growth and development in many soils(Scervino *et al.,* 2011). Regardless of the large volume of P stock present in soils (Imai *et al.,* 2010), soil P release is seldom adequate in meeting the P needs of plants in terrestrial ecosystems (Aerts and Chapin, 1999). This is largely due to multiple forms of P existing in the soils, which differ in their availability for plant uptake across time scales (Hedley *et al.,* 1982; Chen *et al.,* 2003).

Phosphorus exists in two main forms in the soil: "organic and inorganic forms. Organic forms of phosphorus include; available phosphorus, total phosphorus to mention a few while Inorganic phosphorus (P) exists in compounds with Aluminum (Al), Iron (Fe) and Calcium (Ca) in the soil and they exhibit variation in their solubility and availability to plants". Meanwhile, "the chemical fractionation of soil inorganic phosphorus (P) provides a technique for determining the predominant individual forms of inorganic P in soils, most commonly soluble P, aluminum P (Al-P), iron P (Fe-P), occluded P and calcium P (Ca-P) (Chang and Jackson,1957). However, Igwe (2001) asserted that phosphorus fixation is said to be a common occurrence in tropical soils because of the high volume of Iron (Fe) and Aluminum (Al) hydrous oxides. Acidic soils tend to fix either Iron (Fe) or Aluminum (Al) phosphorus compound, while alkaline fix Calcium (Ca) phosphorus compound (Havlin *et al.,* 2001)". Soil characterization provides the information on understanding of the physical, chemical, biological and mineralogical properties of soils determine the forests growth, development and grassland (Ogunkunle and Eghaghara, 1992). Different in land use practices will contain diverse stage, forms of phosphorus as a result of environmental factors and activities that have been taken place on the land. Variations in phosphorus availability and forms can be determined on the various land use (farmland, plantation, degraded sites, and secondary forest). However, many researchers including Chang and Jackson, (1957) as well as Yang and Post, (2011) opined that "soil P fractions determined by sequential fractionation technique can give useful information on the availability and dynamics of soil P and its responses to various environmental or anthropogenic factors in terrestrial ecosystems, and thus have been widely used till date. Therefore, the research work is to determine the factors that responsible for the availability of phosphorus in in different land use types.

Materials and Methods

Study area

The study was carried out at Federal University of Agriculture, Abeokuta, Nigeria. The institution lies between Longitude 7º.23' to 7º.58' N and between Latitude 3 º.25' to 3 º.43' E (Sam-wobo *et al*., 2005).

Experimental Design

The study was a 3×5 factorial experiment laid out in a Completely Randomized Design (CRD) with the following factors; factor 1 the five different land use practices (*Gmelina arborea*, *Tectona grandis*, *Leucaena leucocephala* plantation and Secondary Forest and fallow land) selected within the University location, factor 2 was the soil samples collected from the three soil depths in each location which includes of soils at the depth of (0-30 cm, 30-60 cm and 60-90 cm) from the five different land use practices. Soil samples were analyzed for Phosphorus fractions; calcium phosphate (Ca-P), aluminum phosphate (Al-P), ion phosphate

(Fe-P), available phosphorus (Av-P) and total phosphorus (Total-P).

Soil Preparation and Analysis

The soils samples were collected in polyethylene bags and taken to laboratory for analysis. All soil samples were air-dried for 3 days at room temperature to remove moisture and then sieved through a 2 mm diameter sieve. The characterization of the different forms of inorganic phosphorus in soils was carried out by sequential extraction with acid and alkaline reagents as modified by Chang and Jackson (1957). Based on the extraction using acid and alkaline reagents, originally suggested by Chang and Jackson (Chang and Jackson 1957, Tiyapongpattana *et al.*, 2004) while the Phosphorus concentration in the various extracts was determined using the phosphomolybdate method (Murphy and Riley 1962).

Data Analysis

The data collected were analyzed using two-way analysis of variance (ANOVA). The significant means were separated by the Duncan's Multiple Range Test at $p<0.05$

Results

Effect of depths on the distribution of Phosphorus forms in all the study locations

There were significant differences at $P<0.05$ level of probability among the land use practices, soil depths and interaction between land use and soil depths on Total P, Average P, Aluminum phosphate (Al-P) and Iron phosphate (Fe-P). But no significant difference in calcium phosphate (Ca-P) (Table 1).

The means distribution of different forms of phosphorus with soil depth under different land use practices (LUPs) is presented in Table 2. The result revealed that the highest concentration of calcium bound phosphate (Ca-P) (10.20±0.01) and (10.17±0.01) was recorded at 0-30 cm and 30-60 cm depth while the least concentration of Ca-P (9.16±0.01) was observed at 60-90 cm depth. The result of the soil showed that calcium phosphate (Ca-P) decreased in the soil with increasing in soil depth 0-30 cm, 30-60 cm and 60-90 cm. Aluminum phosphate (Al-P) revealed increase with the increasing in soil depths, The results obtained includes, 0.30±0.02, 0.72±0.00 and 0.95±0.00 mgkg^{-1}. At 0-30 cm, 30-60 cm and 60-90 cm respectively. The highest mean values of AI-P (0.95±0.00) were obtained at 60-90 cm depth followed by 0.70±0.00 at 30-60 cm depth, while the least mean concentration of Al-P 0.30±0.02 was observed at 0-30 cm depth. The concentration of Fe-P decreases with increase in soil depth 0-30 cm, 30-60 cm and 60-90 cm respectively.

Result obtained for Fe-P includes the following, 4.80±0.01, 3.45±0.01and 2.33±0.51at 0-30 cm, 30-60 cm and 60-90cm depth respectively. The highest mean value of Fe-P (4.80±0.01) was recorded at 0-30 cm depth, followed by 3.45±0.01 at 30-60 cm depth while the least mean values of Fe-P 2.33±0.51was obtained at 60-90 cm depth. The results (Table 2) of Available phosphorus (Av-P) from the soil samples collected at depths 0-30 cm, 30-60 cm and 60-90 cm were 7.25±0.03,7.65±0.36 and 8.48±0.01 respectively. The highest values of Av-P (8.88±0.01) were recorded at 60-90 cm depth followed by 7.65±0.36at 30-60 cm depth while the least mean content 7.25±0.03 was obtained at 0-30 cm depth. Available phosphorus values increased in the soil samples with increasing soil depths. The results of the soil samples collected from study locations for total phosphorus (Total-P) depict decreased with increasing in soil depths (0-30 cm, 30-60 cm and 60-90 cm). The highest mean concentration of Total-P (98.52±0.35) was recorded at 0-30 cm depth, followed by 96.49±0.29 at 30-60 cm depth while the least mean value of Total-P (85.43±0.29) was recorded at 60-90 cm depth in the soil studied in the location.

Table 1: Analysis of Variance (ANOVA) for the effects of land use practices and soil depths **on the distribution of phosphorus fractions in the study area**

Parameters	SV	df	SS	MS	F-cal	P-Value
	Soil Depth (SD)	2	30.760	15.38	13610.62	.000*
	Land use (LU)	4	73.519	18.379	16264.60	.000*
Total P	SD*LU	8	17.199	2.150	1902.65	.000*
(Mg/kg)	Error	30	0.034	0.00113		
	Total	44	121.512			
	Soil Depth (SD)	2	27.318	13.659	6535.41	.000*
Average P	Land use (LU)	4	66.630	16.658	7970.33	.000*
(Mg/kg)	SD*LU	8	21.863	2.733	1307.66	.000*
	Error	30	0.0627	0.00209		
	Total	44	115.874			
	Soil Depth (SD)	2	0.00012	0.00006	2000	.000*
Al-P	Land use (LU)	4	0.00037	0.000093	3100	.000*
(Mg/kg)	SD*LU	8	0.0005	0.000063	2100	.000*
	Error	30	0.0001	0.0000000 3		
	Total	44	0.00109			
	Soil Depth (SD)	2	0.00952	0.00476	116.10	.000*
Fe-P	Land use (LU)	4	0.01916	0.00479	116.83	.000*
(Mg/kg)	SD*LU	8	0.00805	0.00100	24.39	.000*
	Error	30	0.00123	0.000041		
	Total	44	0.03796			
	Soil Depth (SD)	2	0.01590	0.00799	1.3613	0.1314 ns
Ca-P	Land use (LU)	4	0.03196	0.00799	1.3681	0.1121 ns
(Mg/kg)	SD*LU	8	0.11968	0.01496	2.5616	0.0615ns
	Error	30	0.17478	0.00584		
	Total	44	0.34232			

***=**significant at P<0.05

ns =not significant at P>0.05

Table 2: Effect of depths on the distribution of Phosphorus forms in all the study locations

Depth	Ca-P	Al-P	Fe-P (mg/kg)	Av-P	Total-P
0-30 cm	10.20±0.01	0.30±0.02	4.80±0.01	7.25±0.03	98.52±0.35
30-60 cm	10.17±0.01	0.72±0.00	3.45±0.01	7.65±0.36	96.49±0.29
60-90 cm	9.16±0.04	0.95±0.00	2.33±0.51	8.88±0.01	85.43±0.29

± standard deviation

Effect of land use on the distribution of phosphorus fractions in the study area

Result presented in Table 3 shows the effect of different land use practices (LUPs) on the distribution, characteristic of various forms of phosphorus fractions in the soil for the five locations (*Gmelina arborea* plantation, *Tectona grandis* plantation, *Leucaena leucocephala* plantation, secondary forest, and fallow land).

The results of Calcium bound phosphate (Table 3) in the soil samples collected from the study location were 5.48±0.02, 2.15±0.02, 5.84±0.01, 3.28±0.02and 3.55±0.01from the different five land use practices (LUPs) (*Gmelina arborea* plantation, *Tectona grandis* plantation, *Leucaena leucocephala* plantation, secondary forest and fallow land) respectively. There was variation in the mean value of Ca-P concentration across the land use practices (LUPs) in the study locations. *Leucaena leucocephala* plantation had the highest mean value of calcium bound phosphate (Ca-P) 5.85±0.01, followed by Gmelina arborea 5.48±02 while the least values of Ca-P (1.55±0.01) were recorded in fallow land. Aluminum phosphate (Al-P) The result obtained for the soil samples collected in each location was recorded as follows *Gmelina arborea* (4.85±0.72), *Tectona grandis* (5.81±0.49), *Leucaena leucocephala* (7.89±0.59), secondary forest (8.53±0.32) and fallow land (5.21±0.15). The highest mean values of Al-P (8.53±0.32) were recorded in secondary forest Al-P content was significantly higher in secondary forest when compared with other land use practices in the soils studied followed by *Leucaena leucocephala* with AI-P (7.89±0.59), while the lowest mean value of Al-P (4.85±0.02) was obtained in *Gmelina arborea* plantation.

The results (Table 3) of the soil samples collected in the study area for the concentration of Iron phosphate (Fe-P) revealed as follows, *Gmelina arborea*, *Tectona grandis*, *Leucaena leucocephala* plantations secondary forest and fallow land with the following mean values 7.65±0.61, 7.09±0.01, 7.23±0.01, 3.19±0.01and 3.53±0.32respectively. The highest mean value of Fe-P content was obtained in *Gmelina arborea* 7.65±0.61, followed by *Leucaena leucocephala* 7.23±0.01. The lowest mean value of Fe-P (3.19±0.01) was recorded in the soil under secondary forest.

The results recorded for the concentration of available phosphorus (Av-P) in *Gmelina arborea*, *Tectona grandis* and *Leucaena leucocephala* secondary forest and fallow land were 4.21±0.02, 6.02±0.00, 9.02±0.00, 6.02±0.00 and 5.03±0.02 respectively. The highest mean value of Av-P was observed in

Leucaena leucocephala 9.02±0.52whilethe least Av-P (4.21±0.02) was found in *Gmelina arborea* plantation. The results (Table 3) of total phosphate in the sampled soil includes, *Gmelina arborea* (95.73±0.17), *Tectona grandis* (96.89±0.00), *Leucaena leucocephala* (112.12±0.16), secondary forest (81.72±0.00) and fallow land (72.62±0.17) respectively. The results obtained from the concentration of Total-P in the land use types ranges from 75.62±0.17to 112.12±0.16, the highest concentration of Total-P was recorded in *Leucaena leucocephala* 112.12±0.16, followed by *Tectona grandis* 96.89±0.00while the least the values for Total-P content were recorded in the soil in fallow land 75.62±0.17 in the study sites.

Table 3: Effect of land use on distribution of phosphorus forms in the study area

Land Use	Ca-P	Al-P mg/kg	Fe-P	Av-P	Total-P
Gmelina arborea	5.48±0.02	4.85±0.72	7.65±0.61	4.21±0.02	95.73±0.17
Tectona grandis	2.15±0.02	5.81±0.49	7.09±0.01	6.02±0.00	96.89±0.00
Leucaena leucocephala	5.84±0.01	7.89±0.59	7.23±0.01	9.02±0.00	112.12±0.16
Secondary forest	3.28±0.02	8.53±0.32	3.19±0.01	6.02±0.00	81.72±0.00
fallow land	1.55±0.01	5.21±0.15	3.53±0.32	5.03±0.02	72.62±0.17

± standard deviation

Discussions

The results of phosphorus fractions in the studied soils varying with soil depths at (0-30 cm, 30-60 cm and 60-90 cm) in the various land use practices (*Gmelina arborea*, *Tectona grandis*, *Leucaena leucocephala*, Secondary Forest and fallow land) with significant differences. The highest Ca-P and Fe-P in the top soil might be due to high concentration of soil organic matter in the soil surface. This is line with findings of (Hou *et al*., 2014). Who reported that, accumulation of organic carbon may increase rather than decrease the availability of phosphorus in surface soil in mature subtropical forest. while the least values of Ca-P and Fe-P observed at the subsoil region might due to the decline in the values of soil nutrient in subsoil with increase in soil depth which in turn affect the amount of Ca-P and Fe-P, within the soil depth examined. Fe-P fraction had the highest values when compared with Ca-P and Al-P in the soil; this may be influenced by variation in climate change, vegetation, parent material and soil management practices.

Fan *et al.* (2020) opined that this could be as a result of the high essential elements which increase the content of Al-P as depth increases. Similar report was obtained from (Siebers *et al*., 2021). This is in agreement with the report (Bekeko *et al*., 2013 and Shen *et al*., 2023). Av-P had the highest content in the soils surface at (0-30 cm) depth, this is similar to the findings of (Mbong *et al*., 2020). Total-P is an inherent property of soils, and decreases with increased in depth. This is in line with the findings of (Messiga *et al*., 2012). The effects of phosphorus fractions on various land use practices (LUPs) in all the study locations. *Leucaena leucocephala* plantation had the highest amount of Ca-P among the land use investigated. Similar result was observed in the findings of (Somasundaram *et al*., 2013), who reported that Ca-P is high under *Leucaena leucocephala* plantation due to high concentration organic elements which in turn increase Ca-P content in the soil study (Paul *et al*., 2008). Highest content of Fe-P obtained in the soil under *Tectona grandis* plantation in all the study area. This result in agreement with the findings of Ogundele, (2012) who reported that accumulation of biomass on the floor of *Tectona grandis* increase Fe-P content in the soil Av-P had a highest significant value under *Leucaena leucocephala* plantation in the soils studied when compared to the others land use types in the studied soil.

The highest content of available phosphorus was observed in *Leucaena leucocephala* plantation might be the reflection of high concentration of organic materials in the soil. Similar report was obtained from Ogundele, (2012) who reported that *L. leucocephala* is rich in available phosphorus due to its ability to increase the of organic materials contents in the soil. The concentration of Total-P in the soils is of little importance in determination of soil fertility. Whereas, it has been used as weathering index to differentiate between highly weathered and less weathered soils (Hunt *et al*., 1976). It is also used as a check on phosphorus balance when the soil is fractionated. The highest values of Total-P were obtained under *L. leucocephala* plantation, this might be attributed to the reflection in high volumes of soil organic materials as *L. leucocephala* known to be nitrogen fixing plant (contained significant values of organic carbon in the soils) which in turn increase the amount of P in the soils. This was in agreement with the report of (Mukhopadhyay *et al*., 2019). The low values of P fractions observed in fallow land in all the land use types in the location might be due to the anthropogenic activities that had been taken place in the location (Zhao *et al*., 2023).

Conclusion and Recommendation

The study revealed that phosphorus content was not uniformed with depths at (0-30 cm, 30-60 cm and 60-90 cm) and land use practices (LUPs) examined in the study locations. Inorganic phosphorus observed in each land use practices were in the following sequential order; *Gmelina arborea* plantation (Fe-P>Ca-P>Al-P), *Tectona grandis* (Fe-P>Al-P>>Ca-P), *Leucaena leucocephala* (Al-P>Fe-P>Ca-P), Secondary Forest (Al-P>Ca-P>Fe-P) and fallow land (Al-P>Fe-P>Ca-P). The study showed that *Leucaena leucocephala* plantation had the highest content of Ca-P, Av-P and total-P, highest Av-P was found in *Gmelina arborea* plantation and the highest Al-P was obtained in secondary forest. The studied indicated that phosphorus fractions were determined by land use management practices. It is therefore recommended that, once there are no substitutes for P in the soils for plants growth, trees planting should be prioritized and proper land use management should be encouraged to improve the availability of phosphorus and others nutrients required by plants.

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