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DISTRIBUTION OF VARIOUS FORMS OF PHOSHORUS IN SOME SELECTED SOILS FROM IBADAN

E. Y. Thomas, J. A. I. Omueti and B. O. Ikhane

Department of Agronomy, Faculty of Agriculture and Forestry, University of Ibadan, Ibadan, Nigeria.
Correspondence: E-mail: thomaseunice@rocketmail.com; Phone: 08077625414

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Abstract

Phosphorus (P) is an essential nutrient element for plant growth and the knowledge of soil P fractions is important for investigating soil P availability and P fertilizer requirement for plants . This study was carried out to investigate the distribution of the different forms of phosphorus (P) in the soils collected at depth of 0-15 cm and 15-30 cm with auger from Parry road, Technology road, Ajibode river valley, and Apata and Laaniba areas of Ibadan. Choice of site location was on the basis of land use practices. Soil samples collected were air-dried, ground and sieved prior to routine laboratory analysis. Various forms of P present in the soils were determined by P fractionation procedure and this procedure is based on separating the inorganic P in the soil samples into six P fractions viz saloid bound P, Al-P, Fe-P, occluded-P (reluctant soluble P), Occluded Fe and Al-P and Ca-P. The NaOH extractable P was taken to be P adsorbed to the surfaces of amorphous and crystalline Al and Fe and the procedure involved six stages of P fractions. Sequential extraction of various forms of P in the soils showed that, there are 47 % of Fe-P, 20 % of Al-P, 12 % of occluded Fe and Al-P, 10 % occluded P and 6 % Ca-P of inorganic P fractions of the selected soils. Saloid bound P (5 %) was the lowest due to absorption in selected soils in this study. It may be necessary to add phosphorus fertilizer to boost the saloid P fractions of these soils as plants take up P mostly in saloid form.

INTRODUCTION

Phosphorus is one of the major limiting factors for plant growth in many soils. Phosphorus, like any other plant nutrient, is present in soil in two major components i.e. organic and inorganic forms. Organic P, which is mainly confined to the surface layer, is mineralized into inorganic forms. But plants mainly depend on inorganic P forms for their P requirements. Saloid-P, Al-P, Fe-P and Ca-P fractions are the main source of P supply to the plants((Singh *et al.,* 2005). Chang and Jackson (1957) first fractionated soil inorganic P into loosely-bound P(saloid-P), aluminum P (Al-P), iron P (Fe-P), calcium P (Ca-P), occluded-P (reductant soluble P) and occluded Fe and Al – P. The relative abundance of the above inorganic forms is indicative of the degree of weathering of the soil, the weathering sequence being in the order: Ca-P, Al-P, Fe-P, and occluded P (Hawkins and Kunze,

1965*;* Westingand De Brito, 1969). The relative proportion of different forms of inorganic phosphorus depends on various soil characteristics like pH, organic carbon, $CaCO_3$, CEC and texture (Jaggi, 1991, Singh *et al*., 2005). Knowledge of forms of phosphorus and their relationship with these soil characteristics is very useful in assessing phosphorus nutrition for plants. The proportion of forms of phosphorus such as Ca-P, Al-P, Fe-P, occluded and organic-P governs the response of plant to applied P (Singh *et al.,* 2003). Such information is meager particularly in the Alfisols of South-western Nigeria. Hence, a study was undertaken to evaluate the distribution of the different forms of P in selected soil.

MATERIALS AND METHODS

Soil Samples Collection

Two soil samples each were collected with the use of soil auger at depth of 0-15 cm top soil and 15-30 cm sub soil from five different locations within Ibadan. A total of 10 soil samples selected. The choice of locations for the selected soil samples were on the basis of land use practices. Ibadan area has a tropical humic climate characterized by high humidity. The mean annual rainfall distribution (mm) of Ibadan is 1485 mm. Temperature ranges between 27.9-34.7°C.The description of the sampling locations, coordinates, land use practices and the USDA soil classification of the selected soils were shown in Table 1.

Soil Analysis

Soil samples collected were air-dried, crushed gently with pestle and mortar and then sieved using 2 mm sieve .Soil physical and chemical parameters were analysed as described by Udo and Ogunwale (1986). Particle size analysis into sand, silt and clay was done using the hydrometer method. Soil pH was carried out on a 1:1 (soil: water) ratio after 10 minutes equilibration period using a glass electrode calibrated to buffers pH 4, 7 and 9. Organic carbon was determined by the dichromate wet oxidation method. Exchangeable acidity was extracted with 1 N KCl and titrated against 0.01 N NaOH. The Effective cation exchange capacity (ECEC) was obtained by summing up of the total exchangeable base (TEB) and total exchangeable acidity (TEA). Total nitrogen was determined by the Kjeldahl method. Exchangeable cations (Ca, Mg, K and Na) were extracted with 1N NH_4OAc (pH 7) at a soil: extraction solution ratio of 1:10 for 15 minutes. Available P was determined using Bray P-1 method.

Phosphate Fractionation Experiment

The soils were separated into their various phosphate fractions using the method described by Chang and Jackson (1957) with some modifications as regards the quantity of soil sample used and the reagents. This procedure is based on separating the inorganic P in the soil samples into six P fractions viz saloid bound P, Al-P, Fe-P, reductant soluble P, occluded-Fe and Al-P and Ca-P. This fractionation procedure is designed to progressively remove less plant available P fraction with each subsequent fraction. The NaOH extractable P is taken to be P adsorbed to the surfaces of amorphous and crystalline Al and Fe (Duffera and Robarge, 1999). The procedure for each stage is explained as follows:

STAGE 1 -Determination of Saloid – P

This was determined by placing 0.5 g soil in 100 ml centrifuge tube and adding 25 ml 1 M NH_4Cl. It was then shaken for 30 minutes, after which the suspension was centrifuged at 2000 rpm for 10 minutes and the clear supernatant was decanted and P was determined.

Table 1: Description of Locations of the Sampling Soils in Ibadan, Nigeria

S/N	Soil Location	Coordinates	Site Description	USDA Classification
1.	Parry Road, U.I	7^0 27' 10" N 3^0 53' 20" E	Cultivated to Plantain	Alfisol
2.	Technology Road, U.I	7^0 26' 24" N 3^0 53' 31" E	Cultivated to Yam	Alfisol
3.	Ajibode	7^0 27' 38" N 3^0 53' 37" E	Valley Bottom	Inceptisol
4.	Laaniba Village	7^0 29' 13" N 3^0 52' 49" E	Fallow Land	Alfisol
5.	Apata	7^0 38' 51" N 3^0 84' 50" E	Cultivated to Maize	Alfisol

STAGE 2 -Determination of Al – P
This was done by adding 25 ml 0.5 M NH_4F adjusted to pH 8.2 to the residue from stage (1) above, followed by shaking for one hour. The suspension was then centrifuged for 10 minutes at 2000 rpm and the clear supernatant was then kept for P determination.

STAGE 3 – Determination of Fe – P
The residue from stage (2) above was washed once with 17.5 ml saturated NaCl by centrifuging at 2000 rpm for 5 minutes and was decanted. 25 ml of 0.1 M NaOH was then added and was shaken for 17 hours (overnight). This was followed by centrifuging for 15 minutes at 2400 rpm and was decanted into a 25 ml conical flask in which 5 drops of concentrated H_2SO_4 was added and gently swirled to flocculate the organic matter and more drops were added to remove colouration from the solution. P was then determined from the clear supernatant.

STAGE 4 – Determination of Occluded–P (Reductant Soluble P)
The residue from stage (3) above was washed once with 12.5 ml saturated NaCl. The soil was then suspended in 12.5 ml of 0.3 M sodium citrate with the addition of 0.5 gsodium dithionite ($Na_2S_2O_4$) salt and was shaken for 5 minutes. The suspension was then heated in a water bath at 85^{o}C for 15 minutes after which it was diluted with 25 ml distilled water. This was followed by shaking for 5 minutes and centrifuging for 10 minutes at 2000 rpm. P was then determined from the clear supernatant.

STAGE 5 – Determination of Occluded Fe and Al – P
The residue in stage (4) above was washed with 12.5 ml NaCl and 25 ml of 0.1 M NaOH was added and was shaken for 17 hours (overnight). The suspension was then centrifuged at 2400 rpm for 15 minutes and P was determined from the clear supernatant.

STAGE 6 –Determination of Ca –P
The residue from stage (5) above was washed with 12.5 ml saturated NaCl and 25 ml of 0.25M H_2SO_4 was added. It was the shaken for one hour and centrifuged at 2000 rpm for 10 minutes. P was then determined from the clear supernatant.
Statistical Analysis
The statistical tools used in the course of this study were standard deviation and mean

percentage descriptive analysis of various amount of inorganic P present in the selected soils.

RESULTS

The Physical and Chemical Characteristics of the Selected Soils

The textural class of the soils is more of sandy loam and loamy sand. Only soils selected from Ajibode soil samples were sandy clay loam both for the soil collected from top and sub-surface horizon. Results indicated that total nitrogen (N) was below critical limit of 1.5 g kg^{-1}(FFD, 2012) for five of the soil samples while the remaining five soil samples were above critical limit of 1.5 kg^{-1}. K, Ca and Mg were above Federal Fertilizer Department (2012) critical limits of 0.15, 0.2, and 0.2 cmol kg^{-1}, respectively. Soil pH (H_2O) ranged from 6 to 7 with an average of 6.6. Therefore, the soils ranged from slightly acidic to neutral. The ECEC of the soils had values ranging from 1.3 – 4.0 cmol/kg across all the selected soilswith an average value of 2.11 cmol/kg. Mean organic carbon ranged from 2.7 to 20.4 g $kg^{-1}$with an average value of 8.99 g kg^{-1} The classification of exchangeable bases in order of abundance in the soils was Na, Mg, Ca, K. Mean values for Na, Mg, Ca, and K were 0.48, 0.44, 0.39 and 0.33 $cmolkg^{-1}$. The available P of the soils ranged from 6 to 30 mg/kg with a mean value of 16 mg/kg .

3.2: Phosphate Fractions of the Selected Soil Samples

In general, the data in Table 3 represent soil P fractionation selected from five locations within Ibadan. It was observed that, over 47 % of the soil P was present in the form of Fe-P and 20 % as Al-P. Occluded P and occluded Fe and Al-P accounted for about 10 % and 12 % respectively. The Ca-P accounted for about 6 % in all the soils. However, the saloid P was the lowest form of P (5%) present in the soils and this occur as a result of the fact that, most of the soil P has been fixed by Fe and Al, thereby making P unavailable in soil solution. In other words, increase in Fe-P and Al-P leads to decrease of P in solution. The decreasing order of P fractions in the soils was Fe-P > Al-P > Occluded Fe-P and Al-P > Occluded P > Saloid P.

Table 2: Chemical properties of some selected soil from Ibadan

S/N	Soil Location	Soil Depth (cm)	pH (H_2O)	O.C.	Total N	O.M.	Av.P	Ex. Acidity	Ca	Mg	K	Na	ECEC	Base Saturation
	……..g/kg……..					…g/kg….		….mg/kg….		…….cmol/kg…..……				
1	Parry Road UI	0-15	6.1	2.7	1.8	4.65	30	0.1	0.4	0.5	0.1	0.2	1.3	923
2	Parry Road UI	15-30	6.8	13.0	1.8	22.4	16	0.3	0.2	0.4	0.3	0.3	1.5	800
3	Tech. Road	0-15	7.0	5.7	1.0	9.83	15	0.3	0.6	0.2	0.2	0.1	1.4	786
4	Tech. Road	15-30	7.1	9.8	1.2	16.9	21	0.5	0.3	0.3	0.1	0.5	1.7	706
5	Ajibode R.V.	0-15	6.6	5.3	1.1	9.14	7	1.5	0.4	0.6	0.7	0.8	4.0	625
6	Ajibode R.V.	15-30	6.4	9.0	1.2	15.5	6	0.7	0.9	0.7	0.1	0.6	3.0	767
7	Laaniba	0-15	6.2	7.3	1.3	12.6	8	0.5	0.3	0.4	0.9	0.4	2.5	800
8	Laaniba	15-30	6.2	20.4	1.2	35.2	7	0.3	0.1	0.5	0.2	0.9	2.0	850
9	Apata	0-15	6.8	8.6	2.1	14.8	27	0.2	0.3	0.6	0.5	0.7	2.3	913
10	Apata	15-30	6.7	8.1	2.0	14.0	24	0.3	0.4	0.2	0.2	0.2	1.4	786
	Mean		6.59	8.99	1.47	15.90	16.1	0.47	0.39	0.44	0.33	0.47	2.11	759.6
	STDEV		0.35	4.88	0.41	8.43	9.02	0.40	0.22	0.17	0.28	0.28	0.87	88.91

O.C. – Organic carbon, O.M. – Organic matter, Ex. Acidity – Exchangeable acidity, Av.P. – Available Phosphorus, ECEC – Effective Carbon Exchange Capacity, Total N – Total Nitrogen, STDEV – Standard Deviation

Table 3: Soil P Fractions in some selected soils from Ibadan

S/N	Soil Location	Soil Depth (cm)	Saloid-P	Al-P	Fe-P	Occluded P	Occluded Fe and Al-P	Ca-P
			---------- mg/kg ----------					
1.	Parry Road, U.I	0-15	2.65	14.30	27.10	8.14	11.94	3.84
2.	Parry Road, U.I	15-30	2.41	16.07	35.52	7.49	10.89	2.74
3.	Tech. Road, U.I	0-15	8.94	12.87	48.44	8.64	2.70	3.49
4.	Tech. Road, U.I	15-30	6.45	21.49	39.24	6.89	5.93	2.54
5.	Ajibode	0-15	4.20	18.10	30.34	4.74	12.99	4.24
6.	Ajibode	15-30	3.28	23.6	42.8	3.49	11.4	3.04
7.	Laaniba Village	0-15	4.51	16.54	31.99	15.74	6.34	2.49
8	Laaniba Village	15-30	3.99	12.29	29.94	15.59	8.44	1.73
9.	Apata	0-15	2.14	10.83	50.67	4.24	14.49	12.39
10.	Apata	15-30	3.33	15.34	41.28	2.29	13.94	11.28
	Mean		**4.19**	**16.14**	**37.7**	**7.73**	**9.91**	**4.78**
	Mean %		**5.21**	**20**	**46.9**	**9.6**	**12.3**	**5.9**
	STDEV		2.08	4.03	8.09	4.67	3.90	3.80

STDEV = Standard Deviation.

DISCUSSION

The sequential extraction of various forms of P in some selected soils of Ibadan showed that, approximately 47 % of P in the soils was present in the form of Fe-P and 20 % as Al-P while occluded P and occluded Fe and Al-P accounted for about 10 % and 12 % respectively. The Fe-P content was highest in the soil surface due to the presence of more organic carbon which provides organic acids which leads to solubilization of iron to ferrous form along with phosphate resulting in precipitation of ferrous phosphate as reported by Sacheti and Saxena (1973). Among the inorganic fractions, Fe-P was dominant over Al-P, occluded P, occluded Fe and Al-P and Ca-P. The Ca-P accounted for approximately 6 % in all the soils, This could be attributed to the fact that Ca-P are dominants in neutral to alkaline soils (Kalaivanan and Sudhir, 2012). The saloid P has the lowest form of P (5 %) present in the soil and this occur as a result of the fact that, most of the soil P has been fixed by Fe and Al, thereby making P unavailable in soil solution. Plants take up phosphorus mostly in the saloid form. In other words, increase in Fe-P and Al-P leads to decrease of P in solution (Sims *et al.*, 1998). The decreasing order of P fractions in the soils was Fe-P > Al-P > Occluded Fe-P and Al-P > Occluded P > Saloid P. Puranik *et al.* (1979) suggested that the presence of Ca-P, Al-P and occluded-P fractions in soils was related to stages of weathering and their solubility. Low amount of Ca-P and high amount of Al-P and Fe-P in the selected soils confirmed that these soils were considered to be more weathered. Low content of Ca-P in the soils might be due to low pH and calcium carbonate content (Negassa and Leinweber, 2009). Saloid - P was the lowest and this might be due to high P fixation

capacity of tropical soils and also due to transformation of soluble forms of P into relatively less soluble forms as time progresses. Similar results were also reported for soils of Tamil Nadu and Karnataka areas in India (Doddamani and Sheshagiri Rao, 1988 and Prakash *et al.*, 1993).

CONCLUSION

In all the inorganic fractions of P, Fe-P and Al-P had the highest percentages than other fractions. The saloid P had the lowest form of P (5 %) present in the soil samples selected and this occured as a result of the fact that, most of the soil P had been fixed by Fe and Al oxides, thereby making P unavailable in soil solution. Phosphorus must be available in the soil in saloid form because plants often take up P in saloid form from the soils.

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