Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension
Volume 11 Number 1 January 2012 pp 33 - 36
ISSN 1119-7455

DISTRIBUTION OF PHOSPHORUS ALONG A TOPOSEQUENCE ON AN ALFISOL IN MINNA, NIGER STATE.

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ABSTRACT
The distribution of various forms of phosphorus was evaluated along a toposequence located in an Alfisol in Teaching and Research Farm of the Federal University of Technology, Minna. The toposequence was delineated into different topographic units (Crest, Upper slope, Middle slope and Lower slope). Soil samples were collected from identified horizons in profile pits in each topographic unit. The soil samples were analyzed for organic, total, available and various active P forms. The results obtained showed that distribution of phosphorus varied widely with each topographic unit. Total P ranged from 102 ug g^{-1} at the lower shope to 422 ug g^{-1}at the upper shope, with a mean of 236.95µg g^{-1}. Organic P also ranged from 21 - 132µg g^{-1} with a mean of 55.8µg g^{-1}. Organic P was highest at the lower slope and lowest at the upper slope. Available P ranged from 0.4 – 5.54µg g^{-1} with a mean of 2.47µg g^{-1}. The active P forms was in the order of Fe-P > Al-P > Ca-P, with Fe-P varying from 19 - 95µg g^{-1}, Al – P ranged from 1.75 – 22µg g^{-1} and Ca – P ranged from 1.12- 4.3µg g^{-1}. There was a positive correlation between organic P and clay (r = 0.56*) and between organic P and organic carbon (r = 0.52*). However, organic P correlated negatively with sand (r= -0.49*).Fe – P and Al – P correlated with magnesium (r = 0.51*) and sand (r = 0.45*) respectively. Available P also correlated positively with clay (r = 0.43*) and organic carbon (r = 0.52*).

Key words: Toposequence, Alfisol, Crest, Active P and Organic P.

INTRODUCTION
Phosphorus (P) is an important nutrient element classified as a macro-nutrient because of its relatively large amount required by plants. Phosphorus plays key roles in many plant processes such as energy metabolisms, synthesis of nucleic acids and membrane, photosynthesis, respiration, nitrogen fixation and enzyme regulation. Phosphorus occurs in various forms in the soil as organic and inorganic. The inorganic P in soil is further classified as iron bound phosphate, aluminium bound phosphate and calcium phosphate (Jianbo *et al*, 2011).
Phosphorus has been identified as one of the most limiting nutrient elements in tropical soils (Ahn, 1993). This low availability of phosphorus in tropical soils is attributed to the nature and forms of the soil phosphorus and the high contents of the oxides of iron and aluminium, which are associated with phosphate fixation (Osodeke and Osondu, 2006).

According to Juo and Moorma (1981), toposequence refers to a succession of sites from the crest to the valley bottom, which contains a range of soil profiles that are representatives of the landscape and soil. Distribution of individual soil series on a toposequences as well as the spatial distribution of the toposequence itself has considerable influence on the soil properties and land use pattern (Ogban, *et al*, 1999). Oluwatosin *et al.* (2001) therefore recommended that agronomic practices be adopted after due consideration of specific topographic locations which might influence mineral availability and fertilizer recommendation.

Since Nigerian soils are highly weathered with low in P status, information about P characteristics is necessary for the

DOI : http://dx.doi.org/10.4314/as.v11i1.5

management of P fertility of Nigerian soils. However, no dealed study on the distribution of P along a toposequence has been conducted. This study was therefore conducted to provide more information on the distribution of phosphorus along a toposequence in an Alfisol in southern guinea savanna zone of Nigeria.

MATERIALS AND METHODS

This study was carried out in Teaching and Research Farm of the Federal University of Technology, Minna (Latitude 9^0 4^{10}N and Longitude 6^0 3^{10}E). The toposequence was delineated into crest, upper slope, middle slope and lower slope. Soil samples were collected from identified horizons in profile pits in each of the topographic units. The samples collected from the identified horizons were air dried, crushed and sieved through a 2 mm sieve. A small portion of the sample was further ground and sieved with 0.5 mm mesh sieve and used for total P, organic P and organic carbon determination.

Particle size distribution was determined by the hydrometer method after dispersion with sodium hexametaphosphate according to the procedure described by I.I.T.A (1976). The soil pH was determined in distilled water and 1.0N KCl solution using a soil - solution ratio of 1:2 (McLean, 1982). Organic carbon was determined by the Walkley – Black wet oxidation method (Allison, 1965). Exchangeable basic cations were extracted with neutral normal ammonium acetate with potassium (K) and sodium (Na) determined by flame photometry and calcium (Ca) and magnesium (Mg) by EDTA titrations (Juo, 1979). Exchangeable acidity was determined titrimetrically using 1.0N KCl extract (McLean, 1982).Available P was determined by the Bray P 1 method (Bray and Kurtz, 1945).Total P was determined by $HCLO_4$ digestion (Jackson, 1958) and organic P was estimated according to Bray and Kurtz (1945) procedure. Inorganic P was fractionated by the method of Chang and Jackson (1957).

The relationships between the forms of P and some of the soil properties were established using simple correlations.

RESULTS AND DISCUSSION

The physical and chemical characteristics of the soils of the study are presented in Table 1.The soils were slightly acidic with pH values ranging from 5.7 to 6.9. The particle size distribution shows that the texture of the soil ranged from sandy loam in the topsoil to sandy clay loam in most of the sub-surface horizons. Although the organic carbon content of the soils was generally low, the accumulation decreases with increase in depth in all the profile pits. Jones and Wild(1975) reported low to medium rate of organic carbon accumulation for savanna soils which was attributed to paucity of vegetation cover, rapid mineralization of organic matter, inadequate return of crop residues, bush burning and short fallow periods. Exchangeable bases were in the order, Ca>Mg>K>Na.

Table 1 : Some physical and chemical properties of the soils studied.

Exchangeable bases								Org. C.	Sand	Silt	Clay	
				Mg	Ca	Na	K					Textural
Profile	Horizon	Depth(cm)										
A	Ap	0 – 20	6.7	1.25	1.60	0.19	0.49	6.39	608.0	132.8	259.20	SL
	AB	20- 45	6.5	0.40	1.00	0.15	0.45	4.77	720.0	54..0	226.0	SCL
	Bt1	45- 80	5.7	1.00	1.20	0.18	0.40	4.07	762.0	20.0	218.0	SCL
	Bt2	80- 96	5.8	0.85	0.80	0.23	0.09	3.95	500.8	78.4	420.8	CL
	BC	96- 110	5.9	0.80	1.25	0.17	0.41	1.48	700.0	56.0	244.0	SCL
B	Ap	0- 15	6.8	0.80	1.88	0.20	0.62	9.37	720.8	118.4	168.8	SCL
	AB	15 – 35	6.4	0.96	1.64	0.26	0.34	5.90	763.0	36.0	210.0	SL
	Bt1	35- 68	5.9	1.15	1.78	0.18	0.44	3.04	730.5	38.5	210 0	SCL
	Bt2	68- 105	6.2	0.60	1.34	0.32	0.55	1.19	680.0	60.0	240.0	SCL
	BC	105- 115	5.8	0.58	0.72	0.21	0.59	1.40	740.2	40.0	218.0	SCL
C	Ap	0 – 18	6.9	1.20	1.82	0.23	0.50	7.08	782.0	40.0	178.0	SL
	AB	18- 39	6.7	0.75	1.67	0.19	0.58	5.42	785.0	35.2	179.8	SL
	Bt1	39- 72	6.6	0.88	1.75	0.18	0.47	2.66	742.0	40.0	218.0	SCL
	Bt2	72-98	5.8	0.73	1.60	0.16	0.33	3.76	750.5	50.2	190.3	SCL
	BC	98-110	5.9	0.68	1.22	0.09	0.40	1.24	730.5	45.5	215.0	SCL

Key: Ap = Plough layer, AB = Transition between A and B Horizon, Bt1 = illuviable layer of clay, Bt2 = increasing intensity of illuviation of clay, BC = Transition between B-horizon and parent materials. SL = Sandy Loam, SCL = Sandy Clay Loam, CL = Clay Loam. A = Crest, B = Upper slope C = Middle slope

Total Phosphorus: As shown in Table 2, the total P content in all the profiles varied from 102 to 422µg g^{-1} with a mean of 236.95µg g^{-1}. These values are comparable to the values reported by Adeleye and Omueti (2006) for some soils derived from basement complex parent material. Total P was generally highest in the upper slope and lowest at lower slope. Also, total P was highest in the topsoils. This trend could be due to accumulation of litters on the topsoil as also suggested by Osodeke and Osondu (2006).

Organic Phosphorus: The organic P was generally low in all the soil series and the values obtained varied from 21 to 132µg g^{-1}. (Table 2) with a mean of 55.8µg g^{-1}.There was appreciable similarity in the organic P distribution among these soil series. Although the values tended to vary according to organic matter content of the soil, organic P decreased with depth in all the soil profiles. Correlation analysis showed that there was a significant and positive relationship between organic P with organic carbon (r = 0.52*) and between organic P and clay content of the soil (r = 0.56*). This significant correlation indicates that organic matter influences the levels of organic P in the soils. Similar trend was reported by Agboola and Oko (1979) in savanna soils of Nigeria.

Available Phosphorus: Available P varied from 0.4 to 5.54µg g^{-1} (Table 2) with a mean of (2.47µg g^{-1}). These values are comparable to the values reported by Osodoke and Osondu (2006). They also confirm the report of Aune and Lal (1997) that most Nigerian soils have the available P less than the critical level of 8µg g^{-1} for the humid tropics. Phosphorus distribution down the profiles did not indicate any particular trend. But topsoils generally had the highest values in most of the profiles. Available P was highest in crest and topsoil and lowest in the middle slope.

Inorganic Phosphorus fractions

The various inorganic P (active P forms) are shown in Table 2. Fe –P varied from 19 to 95µg g^{-1} with a mean of 50.7µg g^{-1}, Al – P varied from 1.75 to 22µg g^{-1} with a mean of 10.96µg g^{-1} while Ca – P varied from 1.12 to 4.3µg g^{-1} with a mean value of 2.47µg g^{-1}. Ca – P had the least value among the active P forms. This could probably be due to the acidity nature of the soils and the fact that it is the most soluble of the inorganic forms and tends to revert to the less soluble iron and aluminium phosphate in acid soils as suggested by Aghimien *et al.* (1988). Fe – P is the least soluble of the inorganic P fraction and tends to accumulate at the expense of the more soluble Ca – P and Al – P and this accounted for the relatively higher content of iron phosphate in the acidic soils (Agbimien *et al*, 1988) and in the order of inactive P> Fe-P > Al –P > Ca – P. Similar order has been reported by several authors (Ibia and Udo, 1993; Adeleye and Omueti, 2006).

Mokwunye and Bationo (2002) also reported that the main sources of plant available P in soils are generally accepted as active P form rather than inactive P form. And secondary Phosphate as Al-P, Fe – P and Ca – P increase in content with strengthening of weathering and pedogenesis in the soil. Lambers et al (2008) suggested that relationship exist between P content and forms in soils and stages of soil development. All soil P is in the primary mineral form (mainly Al- P and Ca – P mineral) at the beginning of soil development. With time, these inorganic P weather giving rise to P in various other forms mainly organic P (reservoir) occluded P and available P.

Table 2: Forms of phosphorus in the soils (mg Kg^{-1})

Profile	Horizon	Total -P	Organic -P	Fe -P	Al-P	Ca-P	Avail.P (Bray – 1)
A	Ap	312	95	42.0	1.75	2.30	5.54
	AB	325	64	33.5	2.00	1.17	5.32
	Bt1	223	38	60.5	3.25	2.50	3.21
	Bt2	257	32	63.0	22.00	4.30	2.12
	BC	105	23	44.0	14.50	3.50	2.54
B	Ap	422	132	20.5	16.25	3.20	4.22
	AB	381	94	19.0	12.00	1.90	5.34
	Bt1	377	53	32.0	13.75	1.17	0.40
	Bt2	241	22	76.0	6.25	2.41	1.32
	BC	143	19	88.0	19.5	2.41	0.79
C	Ap	213	80	32.0	10.25	3.10	2.67
	AB	231	45	16.5	14.75	2.70	2.69
	Bt1	157	38	50.5	2.50	1.12	1.02
	Bt2	154	31	49.0	17.25	3.40	1.22
	BC	137	34	90.5	9.75	4.10	0.61
D	Ap	305	89	33.0	12.5	2.31	3.51
	AB	224	81	26.5	7.50	1.87	2.97
	Bt1	221	78	68.0	16.0	2.36	1.64
	Bt2	209	47	95.5	11.0	4.21	0.88
	BC	102	21	74.0	6.50	2.44	1.30

Table 3. Correlation coefficient between soil P and some soil properties

	Total - P	Organic – P	Fe – P	Al – P	Ca – P	Available – P
pH	0.16	0.05	0.09	-0.09	-0.19	0.25
Sand	0.23	-0.49*	-0.21	0.45*	-0.16	-0.33
Silt	-0.31	0.23	-0.27	-0.26	-0.22	-0.16
Clay	0.23	0.56*	0.34	-0.33	0.26	0.43*
Org. C	-.014	0.52*	-0.25	0.21	-0.14	0.52*
K	-0.12	-0.32	-0.22	0.07	-0.15	0.28
Mg	-0.27	0.26	0.51*	0.05	0.24	0.19

CONCLUSION

In conclusion, this study has shown that the distribution of P along a toposequence varies with topographic units. Also, the P status of the Savanna soils is low and organic matter is found to be influencing available P. Since organic matter content of the surface soil determines the P content of the soil, the surface layer should be protected against natural disasters for effective fertility maintenance especially with regard to P.

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