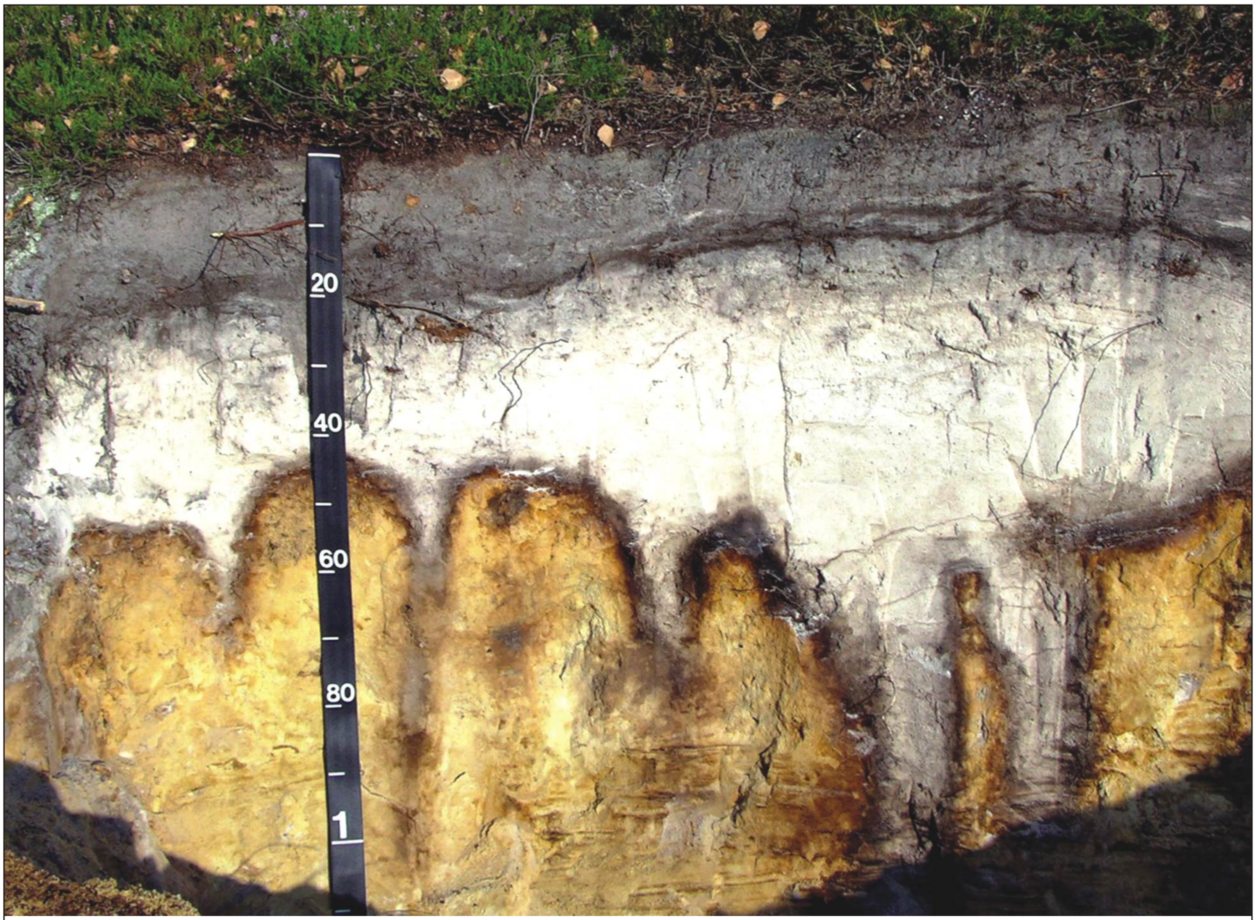

International Journal of

Soil Science

ISSN 1816-4978

Academic
Journals Inc.

www.academicjournals.com

International Journal of Soil Science 2 (3): 197-203, 2007
ISSN 1816-4978

Contents and Distribution of Phosphorus Forms in Some Haplic Plinthaquults in Bauchi Local Government Area, Bauchi State, Nigeria

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Abstract: Studies were conducted to determine the contents and distribution of forms of phosphorus (P) in some Haplaquults in Bauchi Local Government Area (LGA) of Bauchi State, Nigeria. A total of 50 composite soil samples comprising five each of surface 0-15 cm and subsurface 15-30 cm samples were collected from each of five representative locations, namely: Luda, Bayara, Mun, Liman Katagum and Zungur, in the LGA. The soil samples were analysed in the Laboratory using standard procedures. The results indicated that the soils were mostly clay loam, slightly acidic (pH = 4.8-6.6) and low to medium in organic carbon (1.8-12.0 g kg^{-1}). Except for Al-bound (CV = 22.15%) and reductant soluble Fe-P (CV = 37.75%), all the P forms were fairly uniformly distributed in the locations studied. Although both location and depth did not significantly ($p>0.05$) influence the distribution of the P forms, the contents followed the order: total P>Fe-bound P>Al bound P> occluded Fe-Al-P> reductant soluble-P> Ca-bound P> available P. The results also indicated that sand fraction significantly ($p<0.05$) and positively correlated with Ca- and Al-bound P. Improving the drainage condition of the fadama lands and liming are recommended to improve the organic matter mineralization and reduce P fixation, hence, increase the availability of P in the soil.

Key words: Distribution, phosphorus forms, Haplic Plinthaquults

INTRODUCTION

Phosphorus is an essential micronutrient element which has been observed to limit crop productivity (Odiete *et al*., 2005; Attwel and Adams, 1993). In soils, it exists in two main forms: organic and inorganic forms (Busman *et al*., 2002). Each form is a continuum of many P compounds existing in equilibrium with each other and ranging from solution P to very insoluble or unavailable compounds. Inorganic P is usually associated with aluminium (Al), iron (Fe) and calcium (Ca) compounds and varies in their solubility and availability to plants.

Phosphorus fixation is a common phenomenon that occurs in soils with varying degree of occurrence depending on the soil pH. Acidic soils tend to fix Fe- and Al-P, while alkaline soils fix Ca-P (Havlin *et al*., 1995). Phosphorus fixation is known to be a common phenomenon in tropical soils (Igwe, 2001) owing, in part, to their high contents of Fe and Al hydrous oxides. Consequently, the vast majority of the P applied in form of fertilizers becomes fixed and unavailable to plants.

In Nigeria, like in other tropical countries, widespread P studies have shown that the soils are generally deficient in available P (Igwe, 2001). The situation is however less clear-cut in the fadama soils where P studies are far less numerous and the response to P application has been inconsistent (Mustapha and Udom, 2005). With the present drive towards scientific agriculture and the exploitation

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of fadama lands in Nigeria in general and in Bauchi State in particular and in order to meet the food security needs of the country, the need to evaluate the contents and distribution of the various forms of P in the soils becomes imperative.

With the aforementioned in view, this study was conducted with the objective to determine the contents and distribution of the available, organic and inorganic (total inorganic, Ca-bound, Fe-bound, Al-bound, reductant soluble-Fe and the occluded Fe-Al-bound P) forms of P present in some fadama soils in Bauchi LGA, Bauchi State, Nigeria.

MATERIALS AND METHODS

The Study Area

The study was conducted from February to October, 2006 at the fadama areas from Luda, Bayara, Mun, Liman Katagum and Zungur all in Bauchi LGA (longitudes 9°00'; 10°30' N and latitudes 9°30' and 10°30'E), Bauchi State, Nigeria. It is situated in the northern guinea savanna ecological zone of Nigeria. The climate is characterized by high temperature and seasonal rainfall. The mean minimum and maximum temperatures range, respectively, from 10-12°C in December/January and 30-32°C in March-May. The rainfall (1000-1250 mm per annum) is unimodal and lasts from June to October while the dry season starts from late October to May. The soils of the fadama areas are classified as dominantly Haplic Plinthaquults (Mustapha *et al*., 2003a).

Soil Sampling and Handling

Five composite fadama soil samples each from surface 0-15 and subsurface 15-30 cm depths were collected from Luda, Bayara, Mun, Liman Katagum and Zungur; making a total of 50 soil samples. Each sample was a composite of five subsamples collected about 50 m apart.

In the laboratory, each sample was separately air-dried and ground using a porcelain pestle and mortar and sieved through a 2 mm sieve. The fine earth fraction was used for all laboratory analyses.

Laboratory Analyses

Soil samples were analysed using standard procedures as outlined by Page *et al.* (1982). Particle-size distribution was determined by the hydrometer method (Bouyoucos, 1951). The pH (in water) was determined potentiometrically using a glass electrode pH meter in a 1:1 soil: water suspension while organic carbon was determined by the dichromate wet oxidation method (Walkley and Black, 1934). Available P was extracted using the Bray-1 method (Bray and Kurtz, 1945) and determined colorimetrically with a spectrophotometer. The inorganic P fractions (Ca-bound, Al-bound, Fe-bound, reductant soluble Fe-bound and occluded Fe-Al-bound P) were fractionated by the method of Chang and Jackson (1957), while organic-P was determined colorimetrically.

Data Analyses

The data obtained were subjected to simple descriptive statistics and analysis of variance to test the differences between means. Least Significant Difference (LSD) was used to separate the means that were significantly different (Harry and Steven, 1995).

RESULTS AND DISCUSSION

Physico-Chemical Properties

The particle-size distribution of the soils (Table 1) indicates that the sand, silt and clay fractions ranged, respectively, from 23.3-69.5 (mean = 43.4), 10.7-42.4 (mean = 28.6) and 14.9-36.1 (mean = 28.4) % giving the soils a generally sandy clay loam to clay loam texture. The CV range of 9.1-11.8% shows that the sol fractions were fairly uniformly distributed in the soils of the study area.

Table 1: Distribution of particle-size fractions, pH and organic carbon in some fadama soils in Bauchi LGA, Bauchi State, Nigeria

Location	Depth (cm)	Sand	Silt	Clay	Textural class	pH (in water)	Organic C. (g kg^{-1})
		--------------%	------------------				
Luda	0-15	23.3	40.7	36.1	Clay loam	5.83	7.40
	15-30	39.4	32.7	27.9	Clay loam	5.99	2.80
Bayara	0-15	43.4	32.0	24.8	Clay loam	5.76	9.20
	15-30	24.8	39.3	35.9	Clay loam	5.21	13.00
Mun	0-15	44.6	24.0	31.4	Clay loam	6.56	4.00
	15-30	69.5	15.8	14.9	Sandy loam	5.33	1.80
L/Katagum	0-15	42.8	23.1	34.1	Clay loam	4.80	4.80
	15-30	69.5	10.7	19.8	Sandy clay loam	5.29	2.00
Zungur	0-15	40.6	42.4	17.0	Loam	5.33	5.20
	15-30	33.5	41.4	25.1	Clay loam	6.03	2.50
Mean	0-15	50.1	32.4	28.7	Clay loam	5.66	6.12
	15-30	47.8	24.7	28.0	Sandy clay loam	5.57	4.42
CV (%)		11.8	11.3	9.1		3.00	19.70

Table 2: Influence of location and depth on the distribution of phosphorus forms in some fadama soils in Bauchi LGA, Bauchi State

	Forms of phosphorus (mg P kg^{-1})							
Location	Available P	Total organic	Total inorganic	Ca-P	Fe-P	Al-P	Reductant-soluble-P	Occluded Fe-Al-P
Luda	6.12	1972.80	802.66	14.35	354.35	230.95	125.05	77.95
Bayara	7.45	786.40	495.55	20.95	224.65	116.10	68.20	65.65
Mun	6.55	2436.40	671.35	28.95	224.90	321.30	41.85	54.35
L/Katagum	7.05	2287.80	701.05	19.69	356.75	271.25	44.55	74.80
Zungur	11.00	1887.80	748.25	15.00	400.65	243.44	40.45	48.65
Mean	7.63	1874.20	683.77	19.79	312.26	236.61	64.02	64.28
±SE	5.33	654.20	151.03	3.20	46.79	143.44	44.02	12.52
Depth (cm)								
0-15	6.35	2247.30	640.48	18.33	295.08	207.78	47.98	69.30
15-30	8.92	1496.40	753.46	21.26	329.44	265.44	78.06	59.26
Mean	7.64	1871.90	696.97	28.96	312.26	236.61	63.02	64.28
±SE	3.72	1034.30	238.79	5.06	73.98	226.87	69.61	19.79
CV(%)	14.88	17.56	9.64	10.75	9.10	22.15	37.75	9.55

The pH values were generally uniformly distributed between the locations and depths considered (CV = 2.99%) and ranged from 4.80-6.56; implying a moderately acidic to neutral reaction. Organic carbon was generally low in the top 0-15 cm (range = 4.0 -9.2; mean = 6.12 g kg^{-1}) and 15-30 cm (range = 1.8-13.0; mean = 4.42 g k g^{-1}) soils. The results obtained conform to reports by Mustapha *et al.* (2003b) that fadama soils in Bauchi State are generally sandy clay loam to loam, acidic and low to medium in organic carbon.

Forms of Phosphorus

Available Phosphorus

The available P in the soils in the locations studied ranged from 6.12-11.0 (mean = 7.63) mg kg^{-1} (Table 2) and are, according to the rating by Esu (1991), ranging from low to medium. The results also show that available P fraction in the soils was not significantly ($p>0.05$) affected by either depth or location. With a CV of 14.9%, it was observed that available P varied within narrow limits in the soils studied.

The results obtained corroborate the findings of Mustapha *et al.* (2003b) for fadama soils in Bauchi State, but fell below the reported values of 80 mg kg^{-1} obtained elsewhere in Borno State, Nigeria (Rayar and Haruna, 1985). The overall low values of available P in the fadama soils indicate the need for its application to the soils for optimum crop production.

Total Organic Phosphorus

The organic P constituted the largest proportion (71.84%) of the total P in the soils studied (Table 2). Even though both location and depth did not significantly ($p>0.05$) influence the contents of total organic P in the soils studied and a CV of 17.6% indicated a fairly uniform distribution, the fadama soils from Mun contained 2436.4 mg P kg^{-1} while those from Bayara contained 786.4 mg P kg^{-1}. The soils from 0-15 cm depth appeared to have higher (2247.3 mg P kg^{-1}) total organic P than the 1496.4 mg P kg^{-1} in soils at the lower 15-30 cm.

The domination of organic P in these fadama soils may indicate a relative availability of solution P to plants; because bio-available P is transferred to the soil organic matter pool after senescence, which in turn mineralizes to release P into solution P pool as also reported by Bishop *et al*. (1994), Cajuste *et al*. (1995) and Olani and Ae (1999).

Inorganic- P Forms

The distribution of various inorganic P fractions in the soils varied (CV range = 9.55-37.75%) between the locations (Table 2). Luda appeared to have the highest (802.66 mg kg^{-1}) total inorganic P and that from Bayara the lowest (495.55 mg kg^{-1}). The apparent differences were, however, not significant ($p>0.05$).

Ca-Bound Phosphorus

The results in Table 2 show that between locations, Ca-P ranged from 14.4-29.0 mg kg^{-1} and varied within narrow limits (CV = 10.75%). Calcium bound-P is reported to be the dominant inorganic form in neutral to high pH soils (Havlin *et al*., 1995). The amount and distribution of this P form in the soils studied appeared to follow this normal trend of distribution.

It has been reported that the relative abundance of the various P fractions reflects the degree of soil weathering status and development; with Ca-P, Al-P and occluded Fe-Al-P in that order. The relative paucity of Ca-P herein may therefore indicate the intensive weathering status of the soil.

Iron Bound-P

Table 2 shows that Fe-P ranged from 224.65-400.65 mg kg^{-1} between the locations (±SE= 3.20; CV = 9.10%) and apparently increased with depth. The differences were, however, not significant ($p>0.05$). Aaron *et al*. (2000) reported that most inorganic P is associated with non-crystalline Fe compounds, especially goethite and haematite. The likelihood of the presence of these compounds, coupled with the pH of the soil are the major factors contributing to the domination of Fe-P in these soils. The ease with which available P is released seems to be hard due to Fe-P fixation. This justifies the need to use more P fertilizers in order to maintain the critical 0.2 ppm level of solution P in soils as suggested by Sanchez (1970).

Aluminium-Bound Phosphorus

Results in Table 2 show that the Al-P is the second largest occurring inorganic fraction in the locations considered, the first being Fe-P. This observation is contrary to that of Aaron *et al*. (2000) who reported that in acid soils, Al ion is the dominant ion that will react phosphate and hence be the largest in proportion. It is probable that the presence of allophanes (amorphous Al-clay mineral) could be ascribed to the distribution of Al-P in these soils. Allophanes dominate highly weathered soils, which entail high fixing capacities in these soils thereby rendering most of applied phosphate unavailable for plant use, the degree of fixation depends on pH (Havlin *et al*., 1995) with Al-P and Fe-P dominating at pH between 5.0 and 6.5.

Table 3: Correlation coefficients between some selected soil properties and forms of phosphorus in some fadama soils in Bauchi LGA of Bauchi State, Nigeria

	Sand	Organic C	Avail. P	Al-P	Fe-P	Ca-P	Red. Sol.-P	Occluded P	Total inorganic P	Total organic P
Organic C.	-0.758*									
Available P	-0.270	0.327								
Al-P	0.747*	-0.802**	-0.033							
Fe-P	-0.308	-0.048	0.468	-0.072						
Ca-P	0.654*	-0.388	-0.324	0.431	0.400					
Red. Sol.-P	-0.249	-0.102	0.221	0.175	0.234	-0.123				
Occluded P	-0.238	0.149	-0.524	-0.402	0.038	-0.362	-0.325			
Total inorganic P	0.406	-0.714*	-0.055	0.822**	0.445	0.029	0.507	-0.335		
Total organic P	-0.044	-0.365	0.165	-0.046	0.190	0.020	0.204	-0.210	0.089	
pH (in water)	0.085	-0.186	-0.509	0.160	-0.491	0.432	0.281	-0.087	-0.003	0.317

*, ** and ***: Statistically significant at p = 0.05, 0.01 and 0.001, respectively

Reductant Soluble-Fe Phosphorus

The reductant soluble Fe-bound P (Table 2) varied widely between the locations studied (CV = 37.75) and ranged from 125.05-40.45 mg kg^{-1}. The presence/absence of this P form appears to be related to the drainage condition s of the soils. The Fe coatings around the P in this inorganic fraction may be partially or wholly dissolved in anaerobic condition into the solution P. The availability of this P fraction is further determined by prolonged anaerobic condition in which Fe in the soil matrix is reduced from Fe^{3+} to Fe^{2+}, making Fe-P complex much more soluble and causing it to release P into solution (Brady, 1990). The prolonged anaerobic condition may, therefore, make most of the reductant soluble-Fe P relatively available as was also reported by Kparmwang (1996).

Occluded Fe-Al-Bound Phosphorus

The distribution of occluded Fe-Al P in the soil showed a decrease with depth but was uniformly (CV = 9.55%) distributed between the locations (Table 2). The variation with the depth could be as a result of varying degree of aluminum Al and Fe compounds in the varying depths as with earlier reported by Mustapha and Udom (2005) for soils in the area. This variation, however, was not significant (p>0.05).

Correlations

Among the P forms, only Ca-bound P (r = 0.65) and Al-bound P (r = 0.32) correlated with sand fraction (Table 3). This indicates a direct (positive) relation between the P forms and sand fraction corroborating the findings of Hanley and Murphy (1970) that Ca-bound P is largely associated with sand fraction in some Irish soils. On the other hand, the significant positive correlation between Al-bound P and sand contrasts the reports of Kaila (1965) who reported that Al-bound P is predominantly associated with clay and silt fractions.

The various forms of P did not significantly correlate with each other in all the soils, except total inorganic P, which correlated significantly (p<0.01) with Al-bound P. This indicates that increases in total inorganic P were highly contributed by Al-bound P. Although Fe-bound P was found to be the predominant form of inorganic P fraction in the soils studied, the observation that the Al-bound P, can be ascribed to the chemical activity of Al compounds which was reported (Syers *et al*., 1967) that are more fixers of P than amorphous Fe oxide.

CONCLUSION

The results obtained from this study indicate that the contents of the various P forms varied in the order: total organic P> Fe-bound P> Al bound P> occluded Fe-Al-P> reductant soluble-Fe P>

Ca-bound P> available P. It is therefore recommended that management practices aimed at improving the drainage conditions of the fadama soils and liming should be adopted to promote mineralization of the organic P and reduce the P fixation by Fe and Al, hence, increasing the soil available P contents.

REFERENCES

Aaron, J.M., A.G. Edward and A.C. Oliver, 2000. Redox control of phosphorus pools in Hawai in Montana forest soils. Geodama, 102: 219-237.

Attwell, P.M. and M.A. Adams, 1993. Nutrient cycling in forests. New Phytol., 124: 561-582.

Bishop, M.L., A.C. Chang and R.W.K. Lee, 1994. Enzymatic mineralization of organic phosphorus in a volcanic soil in Chile. Soil Sci., 157: 238-243.

Bouyoucos, C.A., 1951. A re-calibration of the hydrometer for making mechanical analysis of soils. Agron. J., 31: 510-513.

Brady, N.C., 1990. Nature and Properties of Soilsm. 10th Edn., Macmillan Publishing Co., New York, USA., pp: 881.

Bray, R.H. and L.T. Kurtz, 1945. Determination of total organic and available forms of phosphorus in soils. Soil Sci., 59: 39-45.

Busman, L., J. Lamb, G.R. Randall and M. Schmit, 2002. The Nature of Phosphorus in Soils. In: Phosphorus in the Agricultural Environment. Regents of the University of Minnesota, Minnesota, FO-06 795-GO., pp: 1-7.

Cajuste, L.J., L. Cruz-diaz, R.J. Laird, R. Carrillogonzalez, G. Palomino and L. Cajuste, 1995. Phosphorus availability in volcanic ash soils. Arid Soil Res. Rehabili., 9: 21-277.

Chang, S.C. and M.L. Jackson, 1957. Fractionation of soil phosphorus. Soil Sci., 84: 133-134.

Esu, I.E., 1991. Detailed soil survey of NIHORT farm at Bunkure, Kano State, Nigeria. Institute for Agric. Res. Ahmadu Bello Unive. Zaria, Nigeria.

Hanley, P.K. and M.D. Murphy, 1970. Phosphate forms in particle size separates of Irish soils in relation to drainage and parent materials. Soil Sci. Soc. Am. Proc., 34: 587-590.

Harry, F. and C.A. Steven, 1995. Statistics: Concepts and Applications. Cambridge Univ. Press, Great Britain, pp: 853.

Havlin, J.L., J.D. Betson, S.L. Tisdale and W.L. Nelson, 1995. Soil Fertility and Fertilizers. 6th Edn., Prentice-Hall, Upper Saddle Diver, New York, USA., pp: 499.

Igwe, C.A., 2001. Free oxide distribution in Niger flood plain soils in relation to their total and available phosphorus. Proceedings of the 27th Annual Conference of the Soil Science Society of Nigeria, pp: 196-201.

Kaila, A., 1965. Some phosphorus test values and fractions of organic phosphorus in soils. Maataloust Aikakoust., 37: 175-185.

Kparmwang, T., 1996. Inherent fertility status of upland and fadama soils in Bauchi State, Nig. Noma. 12: 1-7.

Mustapha, S., G.A. Babaji, L. Singh, B.R. Singh and S.G. Pam, 2003a. Characterization and classification of soils along two toposequences in Northern Guinea Savanna of Nigeria. J. Pure Applied Sci., 6: 189-202.

Mustapha, S., G.N. Udom and A.M. Umar, 2003b. Profile distribution of some physico-chemical properties of some hydromorphic soils of Bauchi State, Nigeria. Nig. J. Agric. Technol., 11: 36-43.

Mustapha, S. and G.N. Udom, 2005. Capability and suitability evaluations of fadama soils for selected crops in the Nigerian Sudan Savanna. Global J. Agric. Sci., 4: 119-124.

Odiete, I., V.O. Chude, S.O. Ojeniyi, G.M. Hussiani and S.O. Ogunmoye, 2005. Response of cotton to nitrogen sources in Guinea savanna zone of Nigeria. Nig. J. Soil Sci., 15: 63-68.

Olani, T. and N. Ae, 1999. Extraction of organic phosphorus in Andosols by various methods. Soil Sci. Plant Nutr., 45: 151-181.

Page, A.L.P., R.H. Miller and D.R. Keeey, 1982. Methods of Soil Analysis. Agron. 9, Part 2, ASA, Madison, Wisconsin, USA.

Rayar, A.J. and B.U. Haruna, 1985. Studies on distribution of total and available nitrogen in the soils of south Chad irrigation project area of Borno State. Ann. Od Borno., 2: 105-110.

Sanchez, P.A., 1970. Properties and Management of Soils in the Tropics. Wiley-Inter Science Publishers, New York, pp: 256-263.

Syers, J.W., J.D.H. Williams, A.S. Campbell and T.W. Walker, 1967. The significance of apatite inclusion s in soil phosphorus studies. Soil Sci. Soc. Am. Proc., 31: 752-756.

Walkley, A. and I.A. Black, 1934. An examination of the D-egtja tef method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci., 37: 29-38.