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# PHOSPHORUS SORPTION CHARACTERISTICS OF ALFISOLS UNDER SELECTED FRUIT TREES SPECIES IN THE ARBORETUM OF FORESTRY RESEARCH INSTITUTE OF NIGERIA

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## ABSTRACT

The importance of phosphorus (P) as an indispensable nutrient for plant growth cannot be overemphasized. Information on Soil P sorption characteristics is important in defining the efficiency of the crops to utilise the phosphorus available in the soil. A study was carried out to investigate the phosphorus sorption characteristics of Alfisols under *Treculia africana*, (TA), *Jatropha curcas* (JC), *Irvingia wombolu* (IW) and *Dacryodes edulis* (DE) plantations in the arboretum of FRIN. This was fitted into a completely randomised design (CRD) with 4 treatments replicated 15 times. 2 g air-dried samples of each soil were subjected to analysis using the methods of Fernandes and Coutinho to study the sorption of P by soils. The Langmuir constants was used to calculate maximum P buffering capacity (PBC) and the external P-requirement of each soil or the amount of P required for each soil at 0.2 mg/L equilibrium solution of P. The phosphorus sorption characteristic of the soils under the four fruit tree species considered in this study has a characteristic S-curve isotherm and this is characterized by an initially small slope that increases with adsorptive concentration. The coefficient of determination ($R^2$) ranged from 0.1620- 0.5050, The sorption maxima (Smax) for all the soils in this study are very low and soil under *Jathropha curcas* (62.0 mg/kg) was significantly higher than those of soils under TA (52.63) and IW (50.25) while soil under DE (42.19 mg/kg) recorded the least. Also, the specific phosphorus requirement of the soils (SPR at 0.2 mg P L-1) ranged from 0.3182 – 0.1565 for all the soils which are high and not cost effective for fertilizer application. It is recommended that P sorption properties of soils should be known to sustain the soil for fruit tree species production in the Institute.

**Keywords:** Phosphorus, Sorption, Soil, Fruit Tree, Langmuir constants.

## Introduction

The importance of phosphorus (P) as an indispensable nutrient for plant growth cannot be overemphasized. Though P is common in nature, its concentration and the amount of its plant available form in the soil is usually low and often inadequate to meet plant requirement (Achalu *et al.*, 2013). Information on Soil P sorption characteristics is important in defining the efficiency of the crops to utilise the phosphorus available in the soil (Fox and Kang, 1978; Rashmi *et al.*, 2015). Langmuir model is one of the most widely used models to describe P sorption characteristics of soils. These models are able to characterised soils based on their ability to adsorb P from soil solutions. And also, they give an insight into the strength of P adsorption on the surface of a particular soil (Wolde *et al.*, 2015). Multiple reports abound on the P sorption characteristic of diverse soil type and conditions within and outside

Nigeria. Udo and Uzu (1972) reported that the capacity to adsorb P varied among various tropical soils within Eastern and Western Nigeria. Wolde *et al*. (2015) also determined the P sorption characteristics/external P requirement of two agricultural soils in Ethiopia. P sorption-desorption isotherms were also studied in some acid upland soils in Indonesia by the Langmuir equation by Hartono *et al*. (2006). The determination of P sorption characteristics of soils is therefore necessary for economic fertilizer application. Likewise, for the recommendation of appropriate management strategies for high P fixing soils (Wolde *et al*., 2015). The P sorption isotherm can be used for the determination of Standard P Requirement (SPR) for most agricultural crops (Rashmi *et al*., 2015). There is paucity of information on P sorption characteristics of soils within the arboretum of Forestry Research Institute of Nigeria. Knowledge of the sorption characteristics of P in the soil for production of fruit tree species is important for designing P management strategies for improving productivity. Therefore, due to specific adsorption of P, it will help to predict availability for assimilation by fruit trees species for better fruit quality.

## Methodology

The study was carried out in the laboratory of the Soil and tree Nutrition section of the Forestry Research Institute of Nigeria Ibadan (FRIN).The study site is located on longitude 07$^{o}$23'18" N to 07$^{o}$23'43"N and latitude 03$^{o}$51'20"E to 03$^{o}$23'43"E. The climate of the area is West African monsoon with dry and wet seasons. The mean maximum temperature of the area at the period of the study was 31.11 $^{o}$C, minimum 22.76 $^{o}$C while the mean daily relative humidity was about 71.8% (FRIN, 2018).The study was laid out as a completely randomized design with 4 treatments replicated 15 times. Surface soil sample at the depth of 0-30 cm was collected using the random sampling method from under the stands of *Treculia africana* (TA), *Jatropha curcas* (JC), *Irvingia wombolu* (IW) and *Dacryodes edulis* (DE) established in the arboretum in 2009. 15 samples each were collected randomly under each plantation making a total of 60 samples. This were placed in a well labelled polythene bag and transported to the laboratory for analysis. The samples were air-dried, crushed and sieved to pass through a 2 mm diameter mesh and then store in plastic bottles. Phosphorus sorption characteristics was determined by batch equilibrium methods in which soil samples were agitated with P solutions of (0, 10, 20, 30, 40, 50 and 100 mgl-1) P concentrations**(**Graetz and Nair, 2008). Phosphorus as ($KH_2PO_4$) was dissolved in a 0.01M solution of Calcium chloride in distilled water. The $CaCl_2$ solution was used as the aqueous solvent phase to improve centrifugation and minimize Cation exchange (Fuhrman *et al.*, 2004).According to the methods of Fernandes and Coutinho to study the sorption of P by soils, 2g air-dried samples of each soil was placed in 100 ml plastic bottle (Fernandes and Coutinho, 1994). A Continuous mixing was provided during the experimental period with a constant agitation speed of 350 rpm for better mass transfer with high interfacial area of contact. Afterwards, calculated amount of stock solution of P for each rate was added. The mixture was shaken for 30 minutes with maximum speed of 380 rpm and equilibrated for 24 hr. After equilibration time, the suspension was filtered through Whatman paper No. 42 filter paper and the concentration of P in the clear extract was determined by ascorbic acid method. The amount of phosphorus sorbed was calculated by subtracting the amount of phosphorus in the extract from the amount of phosphorus initially added. Phosphorus sorbed (mg/kg) against phosphorus remaining in solution (mg/L) was plotted to determine the sorption isotherm. The Langmuir isotherm is described in its linear form in the equation: C/X = 1/K.Xm + C/Xm (Fang *et al.*, 2002; Kleinman and Sharpley, 2002; Xu *et al.*, 2006).Where C is equilibrium phosphorus concentration (mg/L); X is the amount of sorbed phosphorus (mg/kg); m is the constant related to phosphorus sorption maximum (mg/kg) and K is the bonding energy (1 $mg^{-1}$), respectively. The Langmuir constants was used to calculate maximum P buffering capacity (PBC) and the external P-requirement of each soil or the amount of P required for each soil at 0.2 mg/L equilibrium solution of P.

**Results and Discussion**

The capacity to adsorb P varied among various tropical soils within Eastern and Western Nigeria (Udo *et al.*, 1972). The phosphorus sorption characteristic of the soils under the four fruit tree species considered in this study has a characteristic S-curve isotherm and this is characterized by an initially small slope that increases with adsorptive (Figure 1).The relative amount of P sorbed was lower at a low concentration than at a higher concentration as also reported by Tsado (2012). This suggests that the reaction between phosphate and the soil was slower on initial contact; this perhaps could have been due to a high available P content (Figure 1) resulting in low adsorption potential at the surface. Similar observations have been reported by Bala (1992). When soil exhibits S-type curve such as these ones, the affinity of Phosphorus at lower soil solution concentrations up to 0.2 mg P L-1 is higher to the solution than to the soil. However, as the solution concentration of P increases above 0.2 mg kg-1, the situation reverses and the affinity of P will be much higher (Sparks, 2003). This is due to the fact that as concentration of P in soil solution increases, new sorbing sites on the surface of such soils start to open (Sanchez *et al.*, 1997).The coefficient of determination ($R^2$) ranged from 0.1620- 0.5050 under Langmuir (figure 2, 3, 4 and 5). The sorption maxima (Smax) for all the soils in this study are low and soil under *Jathropha curcas* (62.0 mg/kg) was significantly higher than those of soils under TA (52.63) and IW (50.25) while soil under DE (42.19 mg/kg) recorded the least (Table 1). Sarafaz *et al.* (2009) for example reported values ranging from 50 to 201 mg/ kg for surface samples from non-cultivated and non-fertilized areas in Ethiopia in which only one sample having a SPR of 123 mg/kg fell within this range while others had very low SPR values indicating possible early P saturation of these soils following repeated applications of P fertilizers. According to Sanchez and Goro (1980) soils that adsorb less than 150 mg/kg soil to meet the SPR value of 0.2 $mgl^{-1}$ in soil solution are considered to be low sorbing soil and those adsorbing greater than this value are high P sorbing ones. The phosphorus buffering capacity of soil under DE (1.6031) was higher significantly compared to soils from all other fruit tree species considered in the this study which suggest that there will be more phosphorus availability in soil solution of soil under DE when an external supply of phosphorus fertilizer is applied compared to the soil under IW (0.7850) which recorded the least phosphorus buffering capacity and this would encourage leaching of external phosphorus from external fertilizer application (Bala,1992).Several equations have been employed to describe such behaviour, including that of Freundlich and Langmuir (Cornelissen *et al.*, 2004). Since the soil are

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low P sorbing, the specific phosphorus requirement of the soils (SPR at 0.2 mg P L-1) which ranged from 0.3182 – 0.1565 (Table 1) for all the soils are high and not cost effective in use of fertilizer for the production of Fruit tree species in the Institute.

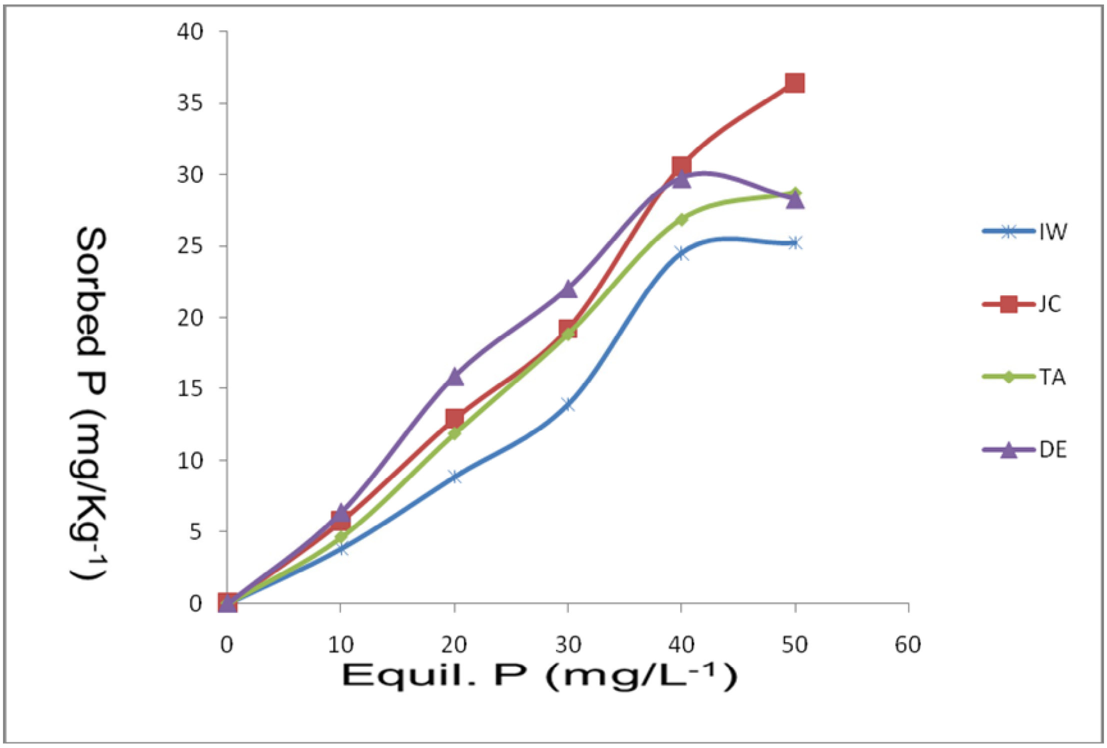


Figure 1: Sorption curve for soil under fruit tree species

**Table 1: Langmuir constants**

| SAMPLE | SLOPE | INTERCEPT | $R^2$ | S-MAX | K | PBC | SPR |
|---|---|---|---|---|---|---|---|
| **IW** | 0.0199 | 1.2739 | 0.1620 | 50.2510 | 0.0156 | 0.7850 | 0.1565 |
| **JC** | 0.0160 | 0.8539 | 0.2236 | 62.5000 | 0.0187 | 1.1711 | 0.2333 |
| **TA** | 0.0190 | 0.9698 | 0.2280 | 52.6320 | 0.0196 | 1.0311 | 0.2054 |
| **DE** | 0.0237 | 0.6238 | 0.5050 | 42.1940 | 0.0380 | 1.6031 | 0.3182 |

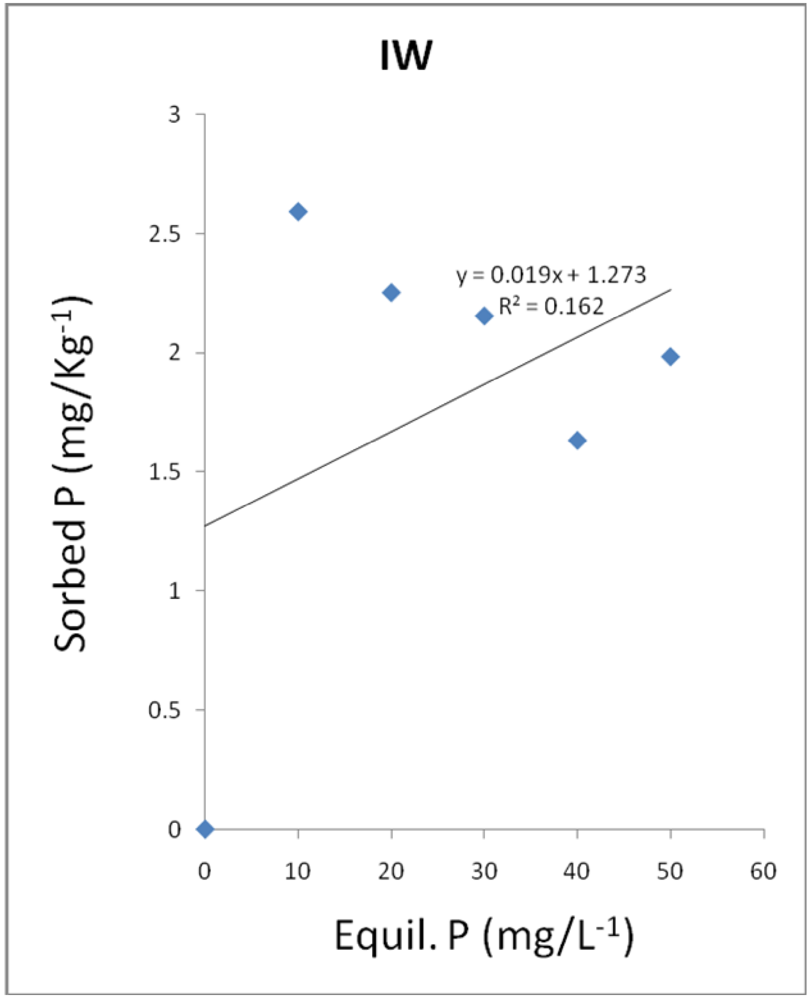


Figure 2: Langmuir Isotherm for Soil under *Irvingia wombolu*

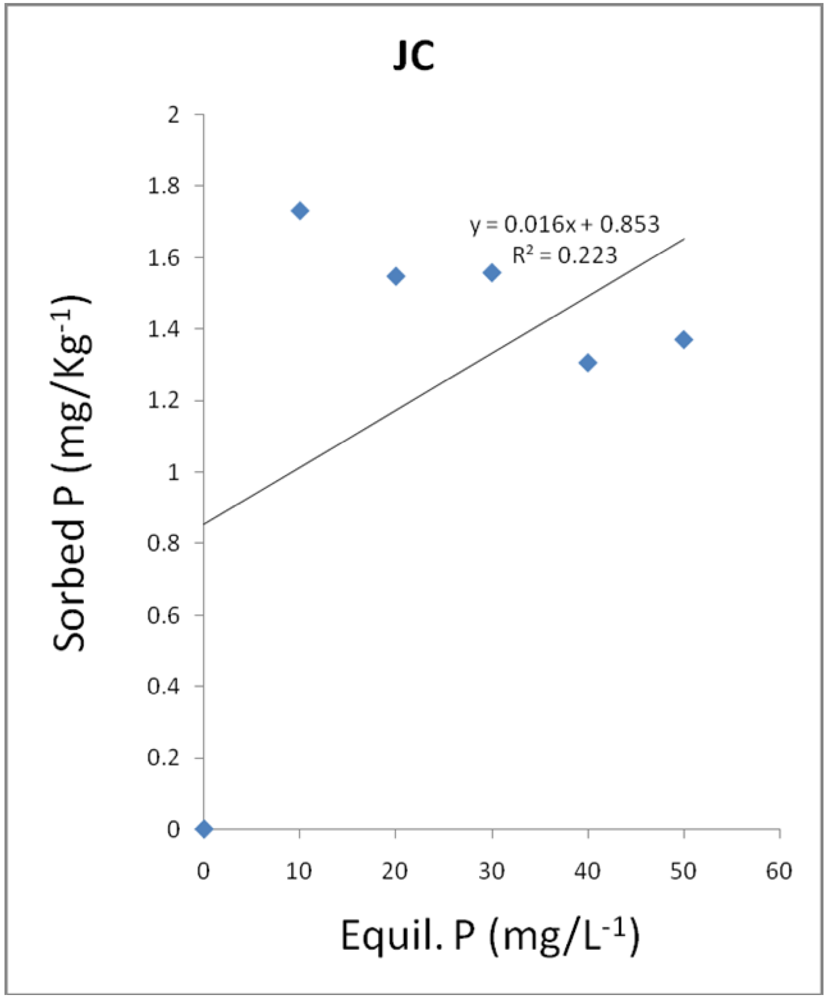


Figure 3: Langmuir isotherm for soil under *Jathropha curcas*

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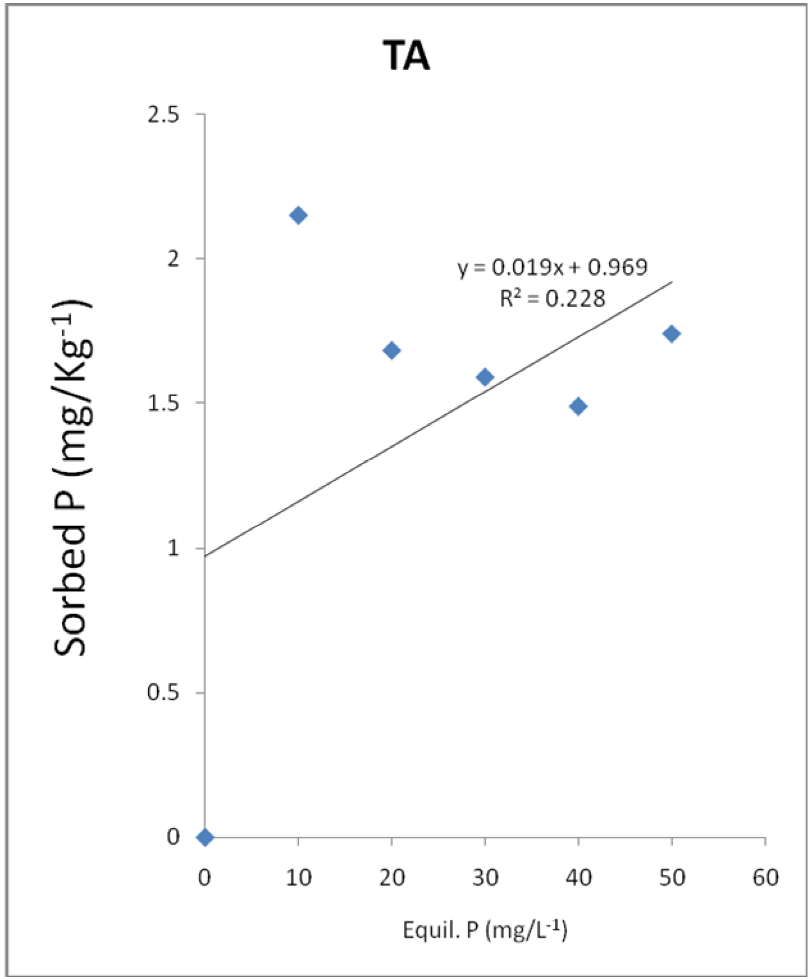


Figure 4: Langmuir isotherm for soil under *Treculia africana*

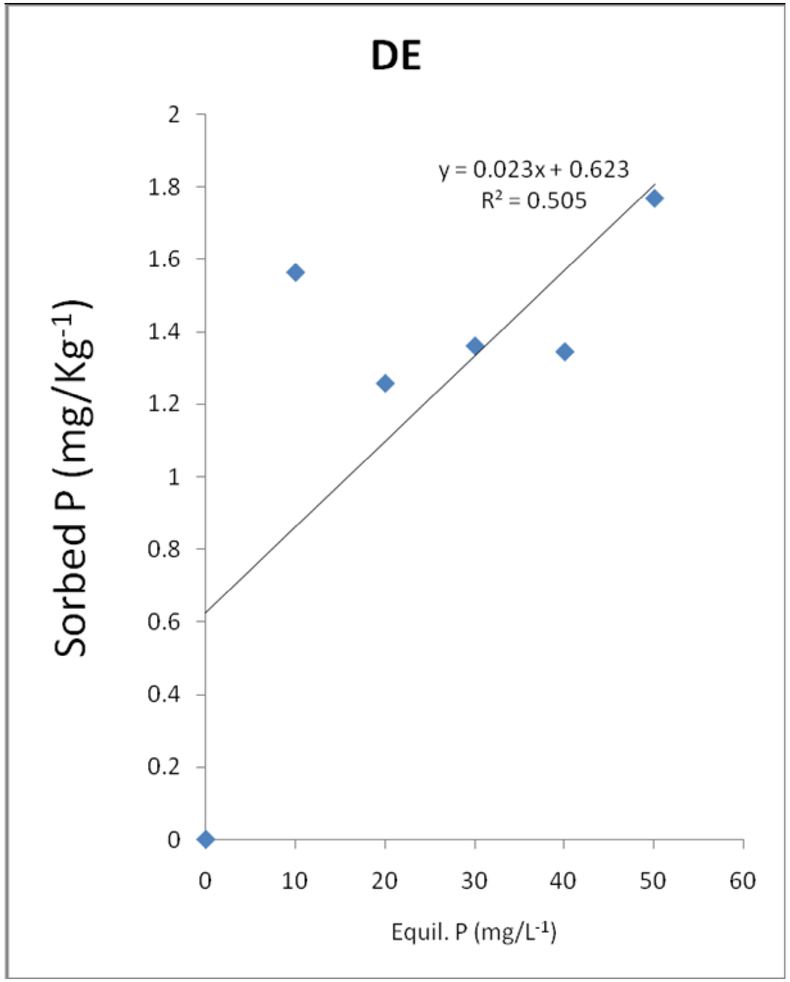


Figure 5: Langmuir isotherm for soil under *Dacryodes edulis*

## Conclusion and Recommendation

Adsorption studies were carried out for soils under fruit tree species and the equilibrium data were tested with Langmuir isotherm model equations and it was recorded that all the soils under the selected fruit tree species in this study has a characteristic S-curve isotherm and it was concluded that the soils are not economically suitable for fruit tree species that requires phosphorus for fruit production due to its low P retention capabilities. A sound knowledge about P sorption properties in different soils is necessary in sustained use of soil for crop production and it was recommended that the production of fruit tree species should be made keeping in view the texture of soils by using the sorption isotherms as this will make fertilizer recommendation to be cost-effective with resultant higher yield.

## References

Achalu C., Heluf G., Abi T. and Kibebew K. (2013). Phosphorus Sorption Patterns of Soils from Different Land Use Systems of East Wollega, Ethiopia. *American-Eurasian Journal of Scientific Research*, 8(3):109-116

Bala A (1992) The effect of phosphate on zinc and copper sorption by a tropical soil. M.Sc. Dessertation. Department of Soil Science, UK. Pp: 33.

Cornelissen, G., Gustafsson, Ö., 2004. Sorption of phenanthrene to environmental black carbon in sediment with and without organic matter and native sorbates. Environmental Science and Technology 38: 148-155.

Fang, F., Brezonik, P. L., Mulla, D. J. and Hatch, L. K. 2002.Estimating runoff phosphorus losses from calcareous soils in the Minnesota River basin. J Environ Qual 31: 1918-1929

Fernandes, M. L. V. and Coutinho, J. 1994. Phosphorus sorption and its relationship with soil properties, Trans. 13th World Congress Soil Science. Acapulco, Mexico, 3b: 103-104.

Fox R. L. and Kang B. T. (1978). Influence of phosphorus fertilizer placement and fertilization rate on soils as measured by the Langmuir isotherm. Soil Science Society of American Proceedings, 65:849-852

Forestry Research Institute of Nigeria (FRIN) (2018). Meteorological Report 2017-18. Nigeria. Unpublished report.

Fuhrman, J. K., Zhang, H. Schroder, J. L., Davis, R. L and Payton, M. E. 2004. Water soluble phosphorus as affected by soil to extractant ratios, extraction time and electrolyte. Commun. Soil Sci Plant Anal.

Graetz, D. A. and Nair, V. D. 2008. Phosphorus sorption isotherm determination, In: J.L. Kovar and Pierzynski, G.M. (ed) Methods of P analysis for soils, sediments, residuals, and waters -So. Coop. Ser. Bull. No. 396, Pp: 35-38.

Hartono A., Funakawa S. and Kosaki T. (2006).Phosphorus Sorption-Desorption Characteristics of Selected Acid Upland Soils in Indonesia. *Soil Science and Plant Nutrition*, 51(6):787-799.

Kleinman PJA, Sharpley AN (2002) Estimating soil phosphorus sorption saturation data from Mehlich-3 data. Commun Soil Sci Plant Anal 33: 1825-1839

Rashmi I., Biswas A. K., Parama V. R. R. and Rao A. S. (2015). Phosphorus sorption characteristics of some representative soils of South India. SAARC Journal of Agriculture, 13(1):14-26.

Sanchez, P.A., Shepherded, K.D., Soule, M. J., Place, F.M., Buresh, R.J., Izac, A., MokwunyeA.U.,Kwesiga, F.R., Ndiritu ,C.G. and Woomer, P.L. 1997. Soil fertility replenishment in Africa: An investment in natural resource capital. In: Buresh, R.J., Sanchez, P.A. and Calhounn, F. (Eds.). Replenishing soil fertility in Africa, SSSA Special publication number 51, Soil Science Society of America, USA. 251 pp.

Sanchez P, Goro U (1980) In: The role of phosphorus in agriculture. Symposium proceeding.ASA, CSSA, SSSA, Madison, Wisconsin, USA, pp. 471-514.

Sarafaz M, Abid M, Mehdi SM (2009) External and internal phosphorus requirement of wheat in Rasulpur soil series of Pakistan. Soil and Environ 28: 38-44.

Sparks, D. L. 2003. Environmental Soil Chemistry, 2nd Edition, Academic Press, Amsterdam, the Netherlands. 352pp.

Tsado P.A., Osunde O.A., Igwe C.A., Adeboye M.K.A., and Lawal B.A (2012) Phosphorus sorption characteristics of some selected soil of the Nigerian Guinea Savanna. University of Nigeria,Nsukka, Enugu State .International Journal of AgriScience Vol. 2: 613-618.

Udo E. J. and Uzu F. O. (1972).Characteristics of Phosphorus Adsorption by Some Nigerian Soils.*Soil Science Society of American Journal*.36:879-883.

Wolde Z, Haile W, Singh D (2015) Phosphorus Sorption Characteristics and External Phosphorus Requirement of Bulle and WonagoWoreda, Southern Ethiopia.Adv Crop Sci Tech 3:169. Doi: 10.4172/2329-8863.1000169 Wolde Z, Haile W, Singh D (2015) Phosphorus Sorption Characteristics and External Phosphorus Requirement of Bulle and WonagoWoreda, Southern Ethiopia. Adv Crop Sci Tech 3:169. Doi: 10.4172/2329-8863.1000169

Xu D, Xu J, Wu J, Muhammad A (2006) Studies on the phosphorus sorption capacity of substrates used in constructed wetland systems. Chemosphere 63: 344-352.