PHOSPHORUS SORPTION AS INFLUENCED BY pH IN ORLU SOIL SERIES OF NIGERIAN INSTITUTE FOR OIL PALM RESEARCH (NIFOR) BENIN CITY.

BY

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BENIN CITY

APRIL, 2024.

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A RESEARCH PROJECT SUBMITTED TO THE DEPARTMENT OF SOIL SCIENCE AND LAND MANAGEMENT IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF SCIENCE B.Sc. (HONS) IN SOIL SCIENCE AND LAND MANAGEMENT, UNIVERSITY OF BENIN, BENIN CITY, NIGERIA.

APRIL, 2024

CERTIFICATION

This is to certify that this project was carried out by Osas Success ORONSAYE (Miss) under the guidance of the project supervisor in the Department of Soil Science and Land Management, Faculty of Agriculture, University of Benin City, Benin City, Edo State, Nigeria.

Prof. E.R. Orhue **Date**
Project Supervisor

Dr. (Mrs.) A.O. Bakare **Date**
Head of Department

DEDICATION

The project is dedicated to God Almighty for seeing me through this programme

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My appreciation goes to God Almighty who by His grace has seen me through the completion of my degree programme.

To the best and amiable Supervisor, Prof. E.R. Orhue, I say a very big thank you for your support, corrections, guidance and encouragement all through the course of this project.

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ABSTRACT

Phosphorus (P) is an important element for plant growth and development, However, P availability is strongly influenced by pH in soils. Hence, this study aims at evaluating P sorption as influenced by pH. This study examined some physical and chemical properties of soil as well as in phosphorus sorption capacity at different pH levels. Soil samples were collected from orlu soil series in Nigeria Institute for Oil Palm Research (NIFOR). Some physical and chemical properties were analyzed using standard procedures in department of soil science and land management resources laboratory, university of Benin. while the influence of pH on sorption was determined by equilibrating the soils with P retention solution containing 1000 mg P L^{-1} as KH_2PO_4 adjusted to exactly pH 3.0, 4.6, 7.0 and 8.6 for 24 hours. The P remaining after equilibration was determined using colorimetrically by the nitric vanadomolybdate yellow method using the spectrophotometer at 466nm. The % P retention was calculated from the graph of absorbency against P retention of the standard solution.The result showed that some physical and chemical properties studied were within the normal range suitable for crop production. The result shows that % P sorption varied with depth and was strongly influenced by pH. The P sorption was least at the neutral pH range of 7.0 with a mean value of 12.90 and was highest at very low pH (pH 3) with a mean value of 26.50. It was also high at alkaline pH range (pH 8.6) with a mean value of 13.84 confirming the influence of pH on P sorption in line with several studies stated in literature All the data collected were subjected to statistical analysis using Analysis of Variance of GenStat Statistical Package and means were separated using Duncan Multiple Range Test of the same GenStat package. It is recommended that farmers in the study area should maintain a neutral pH to minimize P sorption.

CHAPTER ONE

1.0 INTRODUCTION

Sorption is defined as the process of adsorption or absorption which involves the accumulation of molecules or ions on the surface of any substance (Aksu and Isik 2019). However sorption can occur reversibly (desorption) resulting in release of adsorbed nutrient, compounds into the soil solution system. (Arun, *et al,* 2007). There are various factors which influence Sorption such as Soil pH which affects the charge of soil particles and the ionization of sorbates there by influencing their Sorption behavior (Sparks., *et al* 1996). At low (acidic) pH, phoshporus (P) is largely fixed by oxides of Fe, Al, Mn, and clay minerals making it less available for plant use, while at high (alkaline) pH, P is fixed by Ca and Mg compounds forming Ca and Mg phosphate also making it less available (Smith *et al.,* 2023). Therefore it seems that slightly acidic to alkaline pH (6.5-7.3) will Favour maximum availability of P. Nigerian soils are dominated by Sesquioxides and low activity clay (Osayande *et al*., 2013).

This will affect the availability of both native and applied P which is controlled by sorption and desorption and thus influencing its availability to plants, it could therefore be said that Nigerian soils can act as a source or sink of P and may have different sorption capacity resulting from differences in acidity or alkalinity.

In Nigeria, Several studies have been conducted on phosphorus sorption status of different soils (Aghimien *et al,* 2015, Osayande *et al* 2017; Orhue *et al.,*2021). However, there is death of research information on phosphorus sorption as influenced by pH in soils at series levels, Hence this study.

1.1. Objectives of study

The main objective of the study was to evaluate Phosphorus sorption as influenced by pH in Orlu soil series of Nifor. While the specific objectives where to:

(i) determine some physical and chemical properties of the soils.

(i) evaluate P sorption at different pH levels.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Phosphorus

Phosphorus is one of the main essential nutrients for biological growth and plays an important role in soil (Wang *et al*., 2017; Condron and Newman 2011). Its morphology and content are also affected by a variety of factors, and may be subject to variations in response to the evolution of physical, chemical and biological conditions. The form of phosphorus determines its migration, transformation and bioavailability in the environment, and different forms of phosphorus make different contributions to the crop (Zhang *et al.,* 2016). P is the second most important plant nutrient element to nitrogen (N) in terms of its essentiality in increasing the biomass production by plant (Junbao *et al.,* 2014). Phosphorus is important for plant growth and development, playing a critical role in processes such as photosynthesis, energy transfer, and the formation of nucleic acids and proteins (Junbao *et al.,* 2014). Soil phosphorus levels can vary depending on a variety of factors, including soil type, climate, and land use practices. Soil testing can help determine the amount of phosphorus in the soil and can be useful in making decisions about fertilizer applications and other soil management practices. Excessive application of phosphorus can lead to environmental problems such as eutrophication of water bodies, so it is important to carefully manage soil phosphorus levels (Junbao *et al.,* 2014).

2.2. Forms of phosphorus

It is important to study Phosphorus (P) forms and distribution because it has no substitute in the growth of plant. Phosphorus cannot exist alone; it combines with other elements to form phosphate thereby limiting available phosphorus (P) in the soil. Proper management of the soil with regard to the available phosphorus (P) depends on understanding the trend or status of P availability in different land uses within the Edo state. The variations in crops ability to utilize different forms of phosphorus that occurs in soils and the fundamental variation in soil types are some of the major factors affecting the proper understanding of the behaviors of phosphorus in soil. Studies have shown that soils in the tropics like in Nigeria are generally deficient in phosphorus (Igwe *et al*., 2011). The deficiency of phosphorus will limit yield, hence, the need to investigate phosphorus forms and distribution to help devise effective means of soil phosphorus management. Various land use contain different levels and forms of phosphorus as a result of environmental factors and activities that have been carried out on the land. P exists in two main forms in the soil: organic and inorganic forms (Busman *et al.,* 2002). The 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. The chemical fractionation of soil inorganic P provides a method for identifying the predominant individual forms of inorganic P in soils. The most commonly soluble P includes Aluminum P (Al-P), Iron P (Fe-P), Occluded P, and Calcium P (Ca-P) (Chang and Jackson 2017). Soil phosphorus refers to the amount of phosphorus present in soil. Phosphorus is an essential nutrient for plant growth and is typically found in soil in the form of phosphate ions ($PO_4{}^{3-}$).

2.3. Total phosphorus

The total phosphorus in a specific soil sample is referred to as the soil total phosphorus. Phosphorus is one of the important component of fertilizers used in agriculture and is a necessary ingredient for plant growth. To evaluate the overall phosphorus availability and content in the soil, which might affect plant nutrient uptake and production, total phosphorus in soil is commonly evaluated (Adeoye *et al.,* 2017). The process of measuring soil total phosphorus involves chemically extracting phosphorus from the soil and measuring the amount of phosphorus in the extract. To promote the best possible plant growth and yield, this information can be utilized to assess the soil's fertility level and direct fertilization techniques (Adeoye *et al.,* 2017).

2.4 Organic Phosphorus

Soil organic phosphorus (P) is an important component of soil fertility and is an essential nutrient for plant growth and development. In Nigeria, the levels of soil organic phosphorus vary depending on the type of soil, land use, and management practices. One of the major sources of soil organic phosphorus in Nigeria is through the decomposition of organic matter such as crop residues, animal manure, and plant roots (Olibone and Rosolem, 2010). The high temperatures and humidity in Nigeria's tropical climate promote rapid decomposition of organic matter, which releases organic phosphorus into the soil. However, the levels of soil organic phosphorus in Nigeria are often low due to poor soil management practices such as overuse of synthetic fertilizers, deforestation, and land degradation. Synthetic fertilizers often do not contain organic phosphorus, leading to a decrease in the levels of soil organic phosphorus over time. Deforestation and land degradation also contribute to the loss of organic matter in the soil, reducing the availability of soil organic phosphorus (Olibone and Rosolem, 2010). According to Stutter *et al.* (2012), the amounts of organically held phosphorus vary greatly among soils. It occurs from traces in aridisols to several hundred mg kg^{-1} in histosols. Stutter *et al.* (2012) estimated a range from 7 to 1056 mg kg^{-1} P in soil or 20-80% of P in soils worldwide. Decomposing plant and animal products, along with the soil microflora and fauna, provide a significant store and source of organic phosphorus in agricultural systems (Stutter *et al.,* 2012). It is generally assumed that soil organic phosphorus is derived directly or after biochemical transformations of organic matter both among soils and within the soil profile (Cunha *et al.,* 2007). Added P from phosphate fertilizers can also be converted to organic forms (immobilized) especially where there is no enough P in the soil, whereby microorganism convert the inorganic phosphorus to organic phosphorus to incorporate it into their living cells. Soil organic phosphorus exists mainly in stabilized forms as inositol phosphates and phosphonates, and active forms as orthophosphate monoesters, and organic polyphosphates (Nash *et al.,* 2014). The organic phosphorus can be released when roots or phosphate secretions undergo decomposition and mineralization mediated by soil microorganisms (Rita *et al*., 2013). To improve the levels of soil organic phosphorus in Nigeria, farmers can adopt soil management practices such as crop rotation, cover cropping, and conservation agriculture. These practices promote the accumulation of organic matter in the soil, which in turn increases the levels of soil organic phosphorus (Nash *et al.,* 2014). The use of organic fertilizers such as animal manure and compost can also increase the levels of soil organic phosphorus. Soil organic phosphorus is an important component of soil fertility in Nigeria. Its availability is affected by land use, management practices, and the amount of organic matter in the soil. To improve soil organic phosphorus levels, farmers can adopt soil management practices that promote the accumulation of organic matter in the soil and the use of organic fertilizers (Nash *et al.,* 2014).

2.5. Inorganic phosphorus

Inorganic phosphorus (Pi) occurs mainly as $H_2PO^-_4$ and HPO^{2-}_4 adsorbed into the surfaces of oxides and hydroxides of Fe or Al, organic matter or bound to Ca (Olibone and Rosolem, 2010). The adsorption of P in soils depends on soil pH and clay minerals. However, most inorganic phosphorus occurs in the clay fraction as salts of orthophosphoric acid (Duputel *et al*., 2013). Phosphorus forms insoluble compounds with iron and aluminium at low pH, more soluble compounds with calcium and magnesium at pH values near neutrality, and insoluble compounds with calcium at higher pH values (Shen *et al*., 2011 Kruse *et al.,* 2015). There is a wide range of solubility of these various phosphate compounds and their availability to crops is optimal within the soil pH range of about 6.0 to 6.5 for most agricultural soils. The inorganic phosphorus compounds are grouped as calcium or magnesium-bound and iron and aluminium-bound (Kruse *et al.,* 2015)

2.6 Available Phosphorus

Soil available phosphorus refers to the portion of phosphorus in the soil that is readily accessible and available for plant uptake. Unlike total phosphorus, which represents the total amount of phosphorus in the soil, available phosphorus specifically focuses on the fraction of phosphorus that plants can absorb and utilize (Nash *et al.,* 2014). Plants primarily take up phosphorus in the form of orthophosphate ions (H_2PO^{4-} and HPO_4^{2-}). The other forms of phosphorus are not immediately available to plants until they are converted into soluble and accessible forms. The results of available phosphorus analysis help determine the soil's fertility status and the need for phosphorus fertilization. It enables farmers, agronomists, and researchers to make informed decisions regarding phosphorus management, such as adjusting fertilization rates to optimize plant nutrient uptake and improve crop productivity while minimizing potential environmental impacts associated with excessive phosphorus application(Nash *et al.,* 2014).

2.7 Phosphorus fertilizer

Phosphorus is an essential nutrient for plant growth and development. It plays a critical role in energy transfer and other metabolic processes, including cell division and DNA replication. In natural ecosystems, phosphorus is often a limiting nutrient, meaning that plant growth is restricted by the availability of phosphorus in the soil (Wei *et al.,* 2019). Therefore, adding phosphorus fertilizer to soil can increase plant growth and yield. Phosphorus fertilizers come in various forms, including rock phosphate, triple superphosphate, and diammonium phosphate (Sharma and Scherer 2021). The choice of fertilizer depends on the soil pH, the crop type, and the desired outcome. For example, diammonium phosphate is a highly soluble fertilizer that is commonly used in acidic soils. On the other hand, rock phosphate is a slow-release fertilizer that is suitable for alkaline soils. While phosphorus fertilizer can significantly enhance plant growth, excessive use of phosphorus fertilizer can have negative environmental impacts (Sharma and Scherer 2021). Over application of phosphorus fertilizer can lead to runoff into nearby water bodies, causing eutrophication and harmful algae blooms (Ojo *et al.,* 2010). Therefore, it is essential to apply phosphorus fertilizer at the right rate and time to minimize environmental impacts. Phosphorus fertilizer is a critical input for agriculture, but its use needs to be managed carefully to minimize negative environmental impacts (Sharma and Scherer 2021).

2.8. Phosphorus Sorption

Phosphorus sorption refers to the process by which phosphorus (P) is bound to or adsorbed onto soil particles, sediments, or other solid surfaces. It is an important process in the cycling of P in natural and managed ecosystems, as P sorption regulates its availability to plants and microorganisms. P sorption occurs through a variety of mechanisms, including chemical precipitation, ion exchange, and surface complexation (Cardoso *et al.,* 2004). The capacity of soils to sorb P is influenced by several factors, including soil pH, soil organic matter content, soil mineralogy, and the amount and type of P present in the soil solution. Soils with low pH and low organic matter content tend to have a greater capacity to sorb P, while soils with high pH and high organic matter content tend to have a lower capacity. Different forms of P, such as inorganic and organic P, also differ in their sorption capacity, with inorganic P being more strongly sorbed than organic P (Chen *et al*., 2020). Phosphorus sorption is used to describe the processes involved in the removal of phosphate from soil solution, mainly by surface adsorption and precipitation (Del-Campillo *et al*., 1999).

P sorption can have important implications for agricultural and environmental management. In agricultural systems, excessive use of P fertilizers can lead to accumulation of P in soils, which can reduce P availability to plants and lead to P loss through runoff and leaching. In environmental systems, P sorption can influence the availability of P to aquatic ecosystems, with high levels of P sorption leading to decreased P concentrations in surface waters and reduced risk of eutrophication (Chen *et al*., 2020). The conditions under which the soil is created affect the reactivity of the oxides of aluminum and iron. Thus, weakly crystalline oxides with small particle sizes are preferred in cold, humid, and nutrient-poor environments that lead to the accumulation of organic materials, whereas larger, more fully developed crystals form in well-aerated tropical environments.The least crystalline Al and Fe oxides will have the smallest particle sizes and be the most reactive since reactivity is dependent on particular surface areas.(Borggaard *et al.,* 2004). Adsorption is one factor that limits P availability in soil solution by various physical and chemical soil properties and management practices (Tsado *et al*., 2012 Moazed *et al.,* 2010).

2.9 Phosphorus Fixation and its Mechanism

Because of their high concentration of iron (Fe) and aluminium (Al) hydrous oxides, tropical soils are thought to frequently experience the fixation of phosphorus (Havlin *et al*., 2011). The kind of phosphorus fixation that takes place in a soil is determined by its pH; alkaline soil fixes P as a calcium (Ca) phosphate compound, whereas acidic soils typically fix P as an iron (Fe) or aluminium (Al) phosphate compound (Havlin *et al.,* 2011). It has long been known that adding phosphate to soil causes it to quickly become fixed or immobilized. The efficiency and economics of applying fertilizer to a given soil are determined by its capacity to fix more phosphates, which has made this phenomenon of great interest. Different definitions have been given to phosphorus fixing. The following occurrence is understood to be implied by phosphate fixation, according to Devau *et al.* (2010): "When a solution of orthophosphates is applied to soil, there is a decrease in the concentration of phosphates in the solution." Olsen *et al.* (2015) defines fixed phosphorus as the soil phosphorus which has become attached to the solid phase of soils. Phosphate fixation is used to describe any change that phosphorus undergoes in contact with the soil which reduces the amount that the plant roots can absorb (Wild, 2018). The availability changes are not detailed enough to be interpreted quantitatively. A change in solubility does not always translate into a change in availability (Dean, 2018). The processes that are thought to be in charge of fixing phosphorus are as different as the definitions of the process. In 2010, Devau *et al.* proposed the following mechanisms: (A) Phosphate ions precipitate from the precipitates formed by the cations of soluble salts that are present in the soil or by replacing the cations in the soil with those in the solution. (b) Relatively insoluble soil minerals undergo twofold breakdown, which results in the formation of insoluble phosphates. (c) At the large soil-solution contact, phosphates are adsorbed. (d) The minerals in the soil absorb phosphates, forming intricate networks in one or more of the soil solids phases (surface complexation). The types of reaction by which P becomes fixed in soils can be generally grouped as adsorption, isomorphous substitution and by double decomposition involving solubility product relationship (Kardos, 2014).

2.10 Factors influencing phosphorus sorption

Phosphorus (P) sorption is a critical process affecting P availability and mobility in soils. The texture of the soil is one of the critical factors affecting P sorption, with soils having high clay content showing a greater ability to retain P due to their high surface area and cation exchange capacity (CEC). On the other hand, sandy soils with low surface area and

CEC exhibit lower P sorption capacity. This is due to the limited surface area of sand particles, which results in lower interaction with P ions (Sharpley *et al.*, 2012).

Soil pH is another factor influencing P sorption, with soils having a pH close to their point of zero charge (PZC) exhibiting higher P sorption capacity. At a pH close to PZC, the soil surface is electrically neutral, and hence the P ions are attracted and retained by the soil particles. High pH promotes the dissolution of calcium (Ca) and magnesium (Mg) in alkaline soils with high pH levels. These minerals can compete with phosphorus for sorption sites, resulting in the formation of calcium phosphate minerals, which can immobilize phosphorus in the soil and decrease its availability for plant uptake in alkaline soils (Sims and Maguire, 2005). Phosphorus (P) sorption in neutral soils is typically moderate and subject to several influences (Marschner, 2012). Near-neutral pH ranges of 6.5 to 7.5 reduce the solubility of iron and aluminum oxides, which are the main phosphorus sorbents. In addition to minimizing the competition from soluble calcium and magnesium ions, this pH range maximizes the availability of phosphorus for plant uptake. Bünemann *et al.,* 2011). Soil organic matter (SOM) also plays a crucial role in P sorption, as it can form complexes with P ions, leading to lower P availability for plants. The higher the SOM content, the greater the likelihood of P adsorption onto the organic matter (Chen *et al.*, 2020). The amount of soil organic matter (SOM) has a major impact on the soil's ability to sorb phosphorus (P). Because functional groups on organic matter surfaces, like carboxyl and hydroxyl groups, attract and bind phosphate ions, higher SOM content is often correlated with enhanced P sorption (Zhang *et al.*, 2018). Microbial activity uses soil organic matter as a substrate and can affect the dynamics of phosphorus sorption through processes such microbial phosphorus immobilization, organic phosphorus mineralization, and mineral dissolution (Richardson and Simpson, 2011). SOM increases the amount of soil's surface area and gives phosphate ions more places to sorb. The soil's ability to retain phosphorus is improved by this larger surface area (Brady and Weil, 2008). Equilibrating time is an essential factor influencing P sorption, as P sorption is a time-dependent process. An increase in equilibrating time typically results in an increase in P sorption capacity, as the P ions have more time to interact with the soil particles. Thus, P sorption is often measured after a specified period of equilibration time, typically 24 hours or more (Nair *et al*., 2014). Finally, flooding can influence P sorption by altering the soil redox potential. Under anaerobic conditions, the iron and manganese oxides in soils are reduced, resulting in the dissolution of P oxides and a decrease in P sorption capacity. Hence, flooded soils tend to exhibit lower P sorption capacity, which can result in higher P leaching losses (Nair *et al*., 2014).

2.11. Application of Sorption to Agriculture and Environment

The application of sorption in Agriculture and Environmental science is diverse and impactful. It is useful in optimizing nutrient availability in soils to mitigating the impact of pollutants. The following are various ways sorption can be practically applied.

1. Phytoremediation and Sorption: Plants play a vital role in environmental remediation through phytoremediation where they take up and accumulate contaminants. Also sorption processes aids in optimizing plant based strategies for soils and water clean up (Salt *et al.*,1995).
2. Pesticide and Herbicide Sorption: Sorption processes helps in the movement of agrochemicals thereby influencing their availability to plants and potential leaching into surface ground water. However, proper understanding of the movement of pesticides and herbicides in soils is essential for optimizing their efficiency (Wauchope *et al*., 2002).

2.12 Phosphorus Sorption Isotherm/Models

Phosphorus sorption isotherm/models are widely used to study the relationship between phosphorus and adsorbent materials such as soil, sediment, or water treatment media. These models describe the extent and mechanism of phosphorus adsorption onto the surface of the adsorbent materials and can help in developing effective strategies for managing phosphorus pollution in the environment(Cardoso *et al.,* 2004). Commonly used phosphorus sorption models include but not limited to the following: langmuir model, freundlich model, sips model and redlich-peterson model.

Freundlich model

The Freundlich model assumes that the adsorbent material has a range of sites with varying affinities for phosphorus. This model is often used for soils and other heterogeneous materials, as it allows for a more flexible description of the sorption process (Gregory *et al.,* 2005). The Freundlich isotherm equation is:

Where:

q =The amount of phosphorus adsorbed per unit weight of the adsorbent material (mg/g),

C =The concentration of phosphorus in solution (mg/L),

K =The Freundlich adsorption constant $(mg/g)^n$, and

n =The Freundlich exponent, which is a measure of the heterogeneity of the adsorbent material. K and n are constants that depend on the properties of the adsorbent material and the conditions of the adsorption process.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Sites

The study was carried out in Nigerian Institute for Oil Palm Research (NIFOR) which lies between latitude 06° 36'59.7"N and longitude 05° 37'15.8"E in Ovia North-East local government area of Edo state, about 24 km from the state capital Benin City. It is located in the rainforest ecological zone, with an altitude 149.40m, Mean annual temperature of 31°C and a bimodal rainfall regime. NIFOR soils are developed on coastal plain sand and classified into four soil series (local classification) which are Ahiara, Kulfo, Alagba and Orlu soil series. The area where soil samples were collected lies between latitude 06^{0} 33’24.3” N, 06^{0} 33’24.4” N, 06^{0} 33’ 25.8” N, 06^{0} 33’ 26.1” N and longitude 005^{0} 37’30.9” E, 003^{0} 37’ 28.2” E, 005^{0} 37’ 27.9” E, 005^{0} 37’ 31.0” E.

The site was planted to oil palm *(Elaeis guineensis*) as at the time of sampling. The study was carried out on Orlu soil series in NIFOR.

3.1.1 Soil Sampling

Representative soil samples were collected with an auger from four depths (0-30, 30-60, 60-90, and 90-120 cm) in three replications, making a total of twelve (12) samples from field one (Orlu series). The twelve soil samples were labelled in a polythene bag and taken to the laboratory for analysis.

3.2 Laboratory Analysis

Soil samples were air-dried, grounded and sieved through a 2 mm sieve and analyzed for selected chemical and physical properties following the standard procedure.

Table 1: Sampling Point

Rep	Northing	Easting	Altitude (M)
1.	06^0 33’ 24.5	005^0 37’ 30.5”	178
2.	06^0 33’ 24.6”	005^0 37’ 29.2”	164
3.	06^0 33’ 25.8”	005^0 37’ 29.0”	163

3.2.1 Particle Size Analysis

The hydrometer method of Bouyoucos (1962), as modified by Day (1965), was used to determine particle size distribution. 51g of air-dried soil was weighed into a 250-ml beaker, 100 ml of Calgon was added, and the mixture was stirred gently for a few minutes before dispersing with a dispersing machine. The dispersed soil was transferred into a 1000 ml measuring cylinder and made up to mark with distilled water. The suspension was stirred thoroughly with a plunger to set the particles in motion. The first hydrometer reading and temperature was taken after 40 seconds using standard soil hydrometer with Bouyoucos scale in g/L and temperature reading was taken using thermometer. Thereafter the second hydrometer and temperature reading was taken after two hours. The particle size distribution (% sand, silt and clay) was calculated using the formula:

% Sand + % Clay = Corrected hydrometer reading/ weight of sample used × 100.

% Sand = 100 [H_1 + 0.3 (T_1 – 20)–2]2

% Clay = [H_2 + 0.3 (T_2 – 20)–2]2

% Silt = 100 – (% Sand + % Clay)

Where H_1 and H_2 = 1st and 2nd Hydrometer reading

T_1 and T_2 = 1st and 2nd Temperature reading

3.2.2 Textural Classification

Textural classification was determined using the textural triangle (Soil survey staff, 2003).

3.2.3 Soil pH

The soil pH was determined in 1:1 soil: water suspension using a glass electrode pH meter (Tan, 1996).

3.2.4 Organic Carbon

The soil organic carbon (OC) content was determined by the wet oxidation method of walkely and Black (1934).

3.2.5 Total Organic Nitrogen

Total organic nitrogen was determined by dividing the organic carbon values by twenty (Ibitoye, 2008).

3.2.6 Available Phosphorus (P)

Available P was extracted by the Bray-1 solution according to methods by Bray and Kurtz (1945). The P in the extract was developed and read by the Sulphuric acid molybdate blue method of Murphy and Riley (1962).

3.2.7 Exchangeable Bases

Exchangeable bases (Ca, Mg, Na, K) was extracted with 1 N ammonium acetate (1N NH_4OAc), buffered at pH 7. Na and K was read using the flame photometer while Ca and Mg was determined using the Atomic absorption spectrophotometer (AAS).

3.2.8 Cation Exchange Capacity (CEC)

The Cation Exchange Capacity was determined by the summation method after the soils were treated with 1 M NH_4OAc at pH 7.0 (Udo *et al.*, 2009).

3.2.9 Exchangeable Acidity

Exchangeable acidity was determined by extracting soils with 1 M KCl as reported by Juo (1979). The extract was titrated with 0.01 M NaOH solution until a permanent pink color end point.

3.2.10 Effective Cation Exchange Capacity (ECEC)

The ECEC was calculated by the summation of Exchangeable bases and Exchangeable acidity.

3.2.11 Base Saturation

Percentage base saturation was determined by the equation given below:

% Base Saturation = × 100

3.2.12 Determination of Phosphorus Sorption at different pH levels.

3.2.12.1 Preparation of P retention solution

Stock P solution (1000 mg P L^{-1}) was prepared by weighing and dissolving 8.80g Potassium dihydrogen phosphate (KH_2PO_4) and 32.8g of anhydrous sodium acetate in 1 Liter of water. 23ml of glacia acetic acid was added and transferred to a 2 Liter volumetric flask and make to volume of 1950ml with distilled water. Acetic acid (HOAC) or NaOH solution was used to adjust the pH to 3.0, 4.6, 7.0, and 8.6, respectively and made up to volume with water.

3.2.12.2 Phosphorus Sorption Experiment

The sorption study was carried out on twelve (12) soil samples of various depths according to standard procedure recommended by Nair *et al.,* (1984)**,** five (5) grams air dried soil was weighed into series of fifty milliliters (50 ml) plastic bottles, Twenty five milliliters (25ml) of P retention solutions consisting of different pH (3.0, 4.6, 7.0 and 8.6) was added. The suspension was shaked for 24 hours at 20°C using a mechanical shaker, filtered using Whatman No 42 filter paper and P in the filterate was read using the nitric vanadomolybdate yellow method.

3.2.12.3 Preparation of Nitric Vanadomolybdate yellow acid solution

0.9g ammonium vanadate was dissolved in 500ml boiling water, cooled and 6ml conc HNO_3 (70%) was added and diluted to 1 Liter with distilled water. 16g ammonium molybdate was also dissolved in boiling water at 50°C, cooled and diluted to 1 Liter with distilled water. Conc 100 ml HNO_3 (70%) was diluted to 1 Liter with distilled water. The diluted HNO_3 was transferred into a 3 Liter bottle jar, the vanadate solution was added and then the molybdate solution and mixed properly.

3.2.12.4 Standard serial dilution

pipette into 50 ml volumetric flasks 0, 10, 20, 30, 40, and 50 ml of the P retention solution (1000 mg/L) and make to volume with water. The standards corresponds to 100, 80, 60, 40, 20 and 0% P retention respectively.

3.2.12.5 Colorimetric determination of P in filtrate

1ml of standard and sample each was taken into a 25 ml beaker and 19 ml Nitric vanadomolybdate acid solution was added to the sample and standard respectively and allowed to stand for 30 minutes for colour development and homogenization. And read using the 80 UV-Vis spectrophotometer (PG instrument Ltd) at 466 nm.

3.2.12.6 Determination of P Sorption Parameters

A graph of Absorbency (ABS) against % P retention was ploted and the P retention of the sample was calculated from the curve. Since the curve showed a decrease in ABS with a decrease in P concentration (increase in P absorption), the standard solution with the highest P concentration is ploted as the origin of the graph.

3.2.12.7 Statistical Analysis

Data obtained were statistically analyzed using the Genstat statistical package (12th edition). Duncan multiple range test was used to separate means at 5% level of probability.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Some Physical Properties of the Soil Series

Table 2 shows some physical properties of the soil. The result showed that there was a significant ($p < 0.05$) difference between the sand, silt and clay fractions with respect to depth. The result indicated that sand was the highest soil fraction, while silt constituted the least soil fraction. The sand, silt and clay had mean values of 819.90 g, 5.06 g and 12.96 g. The dominance of sand fraction observed in this study is in line with findings of Aghimen *et al.* (2015), Orhue and Emomu, (2022) who reported dominant sand fraction of NIFOR soils.

4 .2 Chemical Properties of the Soil Series

Table 3 shows the chemical properties of soil. The result showed that the pH values range from 5.06 to 5.70, and remains relatively stable across the depth profiles. This suggests that the soil maintains a fairly neutral pH level throughout its profile, which is beneficial for most crops, and closely Organic carbon (OC) content was highest at the top soil (0-30 cm) with a value of (10.34 g kg^{-1}) soil depth, followed by 30-60 cm (6.32 g kg^{-1}) soil depths and remain constant at 60-90 cm and 90 – 120 cm soil depths. However, the OC had mean value of 6.4 g kg^{-1}. The decrease in OC with increase in soil depth could be as a result of litter fall from surrounding vegetation in line with earlier findings of Ogeh and Ogwurike (2006) who reported high organic matter content at surface soils of Midwestern Nigeria. The total organic Nitrogen varied significantly with soil depth, the total organic Nitrogen however ranged between 0.22 g kg^{-1} at 90-120 cm soil depth and 0.52 g kg^{-1} at 0-30 cm soil depths.

Table 2: Some Physical properties of Orlu soil series

Depth (cm)	Sand(g kg $^{-1}$)	Silt (g kg $^{-1}$)	Clay (g kg $^{-1}$)	Textural Class
0-30	882.80^{c}	3.27^{b}	8.52^{b}	Loamy Sand
30-60	838.00^{a}	5.39^{a}	10.81^{b}	Loamy Sand
60-90	787.80^{b}	5.50^{a}	15.71^{a}	Sandy Loamy
90-120	765.00^{b}	6.69^{a}	16.81^{a}	Sandy Loamy
Mean	819.90	5.06	12.96	
Cv	2.30	19.00	9.70	

Mean value (s) with the same letter (s) in the in the column are not significantly different from one another using Duncan's Multiple Range Test (DMRT) at 5% level of probability

Table 3: Some Chemical properties of Orlu soil series

Depth	pH-(	OC	TN	P	Ca	Mg	Na	K	CEC	EA	ECEC	%BS
(cm)	H_2o)	(g/kg)	(mg/kg)	←				(cmol/kg)				→
0-30	5.70^{a}	10.34^{b}	0.52^{b}	0.36^{a}	0.83^{a}	0.26^{a}	0.80^{a}	0.32^{a}	1.49^{a}	0.39^{a}	1.88a	78.30^{a}
30-60	5.46^{a}	6.32^{a}	0.32^{a}	0.36^{a}	0.96^{a}	0.26^{a}	0.08^{a}	0.30^{a}	1.58^{a}	0.42^{a}	2.00a	79.00^{a}
60-90	5.26^{a}	4.47^{a}	0.22^{a}	0.36^{a}	1.26^{a}	0.27^{a}	0.08^{a}	0.19^{a}	1.82^{a}	0.50^{a}	2.32a	77.70^{a}
90-120	5.06^{a}	4.47^{a}	0.22^{a}	0.35^{a}	0.81^{a}	0.24^{a}	0.08^{a}	0.28^{a}	1.40^{a}	0.58^{a}	1.98a	70.80^{a}
Mean	5.37	6.40	0.32	0.36	0.97	0.25	0.08	0.27	1.57	0.47	2.05	76.45
Lsd	0.805	2.503	0.13	0.04589	0.660	0.1087	0.01680	0.2341	0.835	0.3427	0.873	17.45
Cv	8.0	20.8	20.8	6.8	36.3	22.2	11.1	46.1	28.2	38.6	22.7	12.1

Mean value (s) with the same letter (s) in the in the column are not significantly different from one another using Duncan's Multiple Range Test (DMRT) at 5% level of probability.

The result showed that available P showed similar trends as that of total Nitrogen. The exchangeable bases (Ca, Mg, Na and K) were not significantly different with respect to soil depths. The Ca, Mg, Na and K content ranged between 0.81 – 1.26, 0.24 – 0.27, 0.07 – 0.80 and 0.19 – 0.32 cmolkg^{-1} with mean values of 0.97, 0.25, 0.26 and 0.27 cmolkg^{-1} respectively. ECEC values showed variations across depths but lack a distinct depth-related trend. The highest ECEC was obtained at 60-90 cm (2.32 cmolkg^{-1}), while the lowest was obtained at 90-120 cm (1.98 cmolkg^{-1}). The ECEC however had mean value at 2.05 cmolkg$^{-1.}$

4.3. P sorption (%) at different pH in Orlu soil series

Table 4 shows the % P sorption of the soil at different pH levels. The result showed that % P sorption varied at different pH levels across the various soil depths studied. At pH 3 the highest % P sorption was observed when compared with the other pH levels in all the soil depth. At pH 3.0, 4.6, and 7.0, % P sorption was observed to increase significantly with increased soil depth, the % P sorption ranged between 18.50 - 26.50, 11.19 - 21.43, and 7.10 - 14.90 with mean values of 22.90, 16.83, and 12.90 respectively. This increase in % P sorption with increased soil depths aligns with the findings of Orhue and Emomu (2022), who reported increase in adsorption with increase in soil depth using Freundlich model except at 60 - 90 cm soil depth when they reported Freundlich, Langmuir, and Temkin Isotherm studies of silicon sorption on soils derived from three parent materials in Edo state, Nigeria. The result showed that % P sorption was least at the top soil (0 - 30 cm) soil depth for all the pH levels studied. This low % P sorption at the top soil could be attributed to occurrence of higher organic carbon content at the top soil as organic carbon is known to reduce sorption capacity whic is in line with the findings of Asmare *et al*., (2015) who reported phosphorus status, inorganic phosphorus status and other physiochemical properties of acid soils of farta district,northwestern highlands of ethiopia. It was observed that % P sorption was highest at 90 - 120 cm soil depth. The most striking finding of this study was that the % P sorption was lowest in all the soil depth at pH 7.0 when compared with other pH levels. This affirms better availability of P at a neutral pH range (6.3 - 7.5) due to reduced p sorption capacity as reported widely in literature. The results indicate that p will be more available around this pH range due to decrease in P sorption. This result of low P sorption at pH 7.0 (neural pH) is in line with the findings of Zhang *et al.* (2020) who reported effects of soil pH on phosphorus sorption and availability in different textured soils highlighting that % P sorption tends to decrease as soil pH approaches neutral range, leading to better P availability at the pH range of 6.3 - 7.5. The result at pH 8.6 showed that % P sorption increased with increased soil depths. This increase with increase in soil depths found by this study is contrary to the findings of Chen and Barber (1990) who observed a decrease in P sorption with increased soil depths.The highest P sorption values are consistently found at (90 – 120 cm) soil depth as P sorption increase, followed by 60–90 cm. In contrast, the shallowest depth (0–30 cm) shows the lowest P sorption but becomes less effective in retaining P as sorption increase. The increase in P sorption recorded in this study agrees with Adeoye *et al*. (2017) who reported that soils in Nigeria generally have a high phosphorus sorption capacity due to their high clay content and the presence of iron and aluminium oxides.

Table 4 : P sorption (%) at different pH Levels

Depth	3.0	4.6	7.0	8.6
0-30	18.50^{a}	11.19^{a}	7.10^{a}	10.54^{a}
30-60	22.10^{ab}	15.81^{b}	17.30^{a}	14.58^{ab}
60-90	24.40^{ab}	18.90^{bc}	12.30^{a}	14.12^{ab}
90-120	26.50^{b}	21.43c	14.90^{a}	16.12^{b}
Mean	22.90	16.83	12.90	13.84
SEM	2.14	1.121	3.32	1.461

Mean value (s) with the same letter (s) in the in the column are not significantly different from one another using Duncan's Multiple Range Test (DMRT) at 5% level of probability

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study showed Some physical and chemical properties of the soil as well as the % Phosphorus Sorption at different pH (3.0, 4.6, 7.0, and 8.6). The soil was found to be predominantly sandy in nature, with sand being the dominant fraction. Silt content was relatively low across all depths, indicating a potential requirement for organic matter or soil amendments to enhance soil fertility and water-holding capacity. Clay content decreased with increasing soil depth. The soil pH remained relatively stable throughout the depth profiles. Organic carbon content was highest in the topsoil and decreased with increasing soil depth. This study showed variation in P sorption across different depth at the various pH levels, with pH 3.0 exhibiting the highest % P sorption and pH 7.0 having the least % p sorption indicating suitability of this pH range (pH 7.0) for optimum p availability.

5.2 Recommendations

Based on the findings of this study , the following recommendations can be made:

1. The soil physical and chemical properties studied were still within the levels suitable for crop production and thus farmers should adopt conservation management practices to avoid degradation of soil the soil properties.
2. Before P fertilization farmers in the study area should ensure that the soils are within neutral pH range (6.3 - 7.5) to reduce sorption of applied P and enhance adequate P mineralization for plant utilization.

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