ABSTRACT

The mechanism of P retention in Nigerian soils are rather complex and difficult to understand. Many researchers, however, view P retention as continuum embodying precipitation, chemisorption, and adsorption, if the processes are viewed throughout the entire zone of soil influenced by fertilizer application and throughout a time span encompassing an entire growing season or longer. However, it is important to note that P retention in Nigerian soils is influenced by many factors such as P concentration in solution, amount of hydrated oxides of iron and aluminum, soil pH, organic matter, type and amount of clay, exchangeable Al and parent materials.

Phosphorus is one of the major essential elements required by plants for normal growth. It is a constituent of nucleic acids, phytin and phospholipids. Phosphorus is associated with early maturity of crops, particularly the cereals, and is considered essential to the seed formation. In many plants, phosphorus deficiency is recognised by the purple and sometimes bronze, tinge of the leaves, which are generally characterized by a dull bluish green colour with purple or brown spots. It is absorbed by the plants either as monohydrogen orthophosphate (HPO$_4^{2-}$) or dihydrogen orthophosphate (H$_2$PO$_4^-$) depending on the soil pH.

Fertilizer trials have shown that majority of the soils of the humid tropics are deficient in P (Olson and Engelsted, 1972). Generally, the available P status of these soils is so low that some P fertilizer must be applied for even moderate yield. In some soils of the savanna zone of West Africa, for example, P deficiency is so acute that plant growth ceases as soon as phosphorus stored in the seed is exhausted (Mokwunye et al., 1986).

The availability of applied P is controlled by retention (Sorption) and release (desorption) characteristics of the soil. Tropical soils particularly the highly weathered ones like Nigerian soils often have a high P retention power. The reactions involved in these phenomena are complex and range from true adsorption to precipitation (Harter, 1969). A proper understanding of P retention mechanism in Nigerian soils is very important for P fertilizer management practices, hence the justification of this review.

PHOSPHORUS RETENTION IN NIGERIAN SOILS

The removal of P from dilute solutions by soil constituents has been described by several different adsorption equations. Langmuir, Freundlich and Temkin equations, or modifications of these have been used most frequently. All are based on the fundamental equation:

\[ q = F(c) \]

where, q is the quantity of P adsorbed at P concentration c.

One of the earliest used in soil studies is the Freundlich equation:

\[ q = ac^b \]

where, q is the amount of adsorbed P per unit weight of soil, c is the P concentration in solution, and a and b are constants which vary from soil to soil.

Langmuir equation was first applied to adsorption of P in soils by Olsen and
Watanable (1957). Although there are several linear forms, they are derived from the basic expression:

\[ q = \frac{kbc}{1+kc} \]

where, \( q \) and \( c \) are as in the Freundlich equation, \( b \) is the P adsorption maximum and \( K \) is the constant related to bonding energy. The equation implies that all increments of sorbed P are held with the same bonding energy (constant \( K \)) and that there is a maximum sorption capacity that will not be exceeded regardless of increasing concentrations.

The Temkin equation as proposed for use in soil P system by Bache and William (1971), also implies that the energy of adsorption decreases as the amount P sorbed increases. In the middle range of P sorption the equation may be expressed as

\[ q/b = (RT/B) \ln(Ac) \]

where, A and B are constants and \( b, c \) and \( q \) are as in the Langmuir's equation.

Ataga and Omoti (1978) studied phosphate sorption characteristics and the use of sorption isotherms for evaluating the phosphate requirements of the oil palm on some acid sand soils of Southern Nigeria. All the soils they used for the study sorbed from little to moderately large amounts of phosphate. The phosphorus adsorption maxima ranged from 35.5 to 387 ppm P, the soils derived from Basement complex rocks were having higher adsorption maxima than the acid sand soils. Phosphorus adsorption was significantly correlated with Al and Fe sesquioxides, exchangeable AI as well as the clay content. The AI and Fe sesquioxides both accounted for 68.0 per cent of the variation observed in phosphate sorption.

Juo and Fox (1977) evaluated phosphate sorption characteristics of soil materials from selected soil profiles of West Africa. These soils represented a wide range of parent materials and agroclimatic conditions. Phosphate concentration in soil solution was almost invariably low in comparison with requirements for most crops. In comparison with many soils of humid tropics, the surface had low to medium standard P requirements. They observed that phosphorus sorption capacity was mainly related to soil mineralogy, which in turn is related to soil parent materials, BET - surface area, and Free oxides content of the soils of the profiles studied, ultisols and ultisols derived from basalts had the highest standard P requirements. Ultisols had higher standard P requirements man Alfisols.

Juo and Maduakor (1974) studied the phosphate sorption of some Nigerian soils and its effect on cation exchange capacity. They reported that the phosphate sorption capacity of the soils they studied follow the order: Alfisols from basalts > Ultisols from sandstones > Alfisols from basement complex rocks (gneisses) = Alfisols from coastal sediments = Alfisols from eolian drift. The sandy forest soils derived from basement rocks and from coastal sediments in South - Western Nigeria required relatively low amounts of phosphate for maximum crop yield as determined by the Langmuir isotherm. Udo and Dambo (1978) evaluated the phosphorus status of the Nigerian coastal plain sands. They reported that the adsorption capacity varied widely among the soils. The amount adsorbed from the addition of 150mg/100g soil ranged from 40.2 to 86.2 mg/100g and was related to the clay content. They observed that the subsoils generally adsorbed more P than the surface soils.

Udo and Uzu (1972) evaluated the characteristics of phosphorus adsorption by some Nigerian soils. They reported that adsorption was significantly correlated with sesquioxides and the exchangeable forms of Al and Fe as well as the clay content and pH. The citrate - dithionite and the oxalate
extractable oxides were of equal significance in the phosphorus adsorption, but the role of Al was more important than that of Fe.

Aghimien et al. (1985) studied the phosphorus status of hydromorphic soils from Southern Nigeria. They observed that the standard P requirement (SPR) which is the amount of P adsorbed at 0.2 mg/liter of the equilibrium solution concentration ranged from 0 to 452 mg/kg with average value of 157 and 141 mg/kg for soils on basement complex rocks and sedimentary deposits, respectively. The capacity of the soils to adsorb P was related to exchangeable Al, organic carbon, clay content and free Fe$_2$O$_3$, and inversely to the available P.

Loganathan et al. (1987) assessed phosphorus sorption at equilibrium concentration of 0.1 - 2ppm in 0.01M CaCl$_2$ using 42 samples from highly acidic surface layers of ultisols and inceptisols from three major geomorphological regions of Niger Delta of Nigeria. The data conformed to the Langmuir Isotherm. The Langmuir sorption maxima and sorption at 0.2 ppm equilibrium P concentration ranged from 100 - 767 µg P/g soil and 30-240 µg P/g soil, respectively. This indicated that the soils samples had low to medium P fertilizer requirements. Sorption capacities were significantly correlated with percentage of clay and silt, surface area, and different forms of Fe and Al, but not with pH and organic matter.

Osodeke and Omueti (2000) evaluated the phosphorus sorption characteristics of soils of the forest zone of South Western Nigeria. They observed that the standard P requirement of the soils they used for study correlated significantly with DCB extractable Fe and Al Oxides, while the adsorption maximum correlated significantly with clay content and exchange acidity.

Osemwota et al. (2000) carried out characterization of soils of Edo State of Nigeria for the computation of phosphorus fertilizer factor. They observed that the quantity of applied P (kg/ha) required to raise the soil test value by a unit amount (mg/L), i.e. the P fertilizer factor varied from 1.28 to 2.50 with a mean of 1.76. They also reported that the level of P sorption was influenced by free Fe$_2$O$_3$.

Omoregie and Akenova (1999) evaluated P status and sorption capacities of some native range land soils in Northern Nigeria. They reported that the P sorption capacity was positively related to the clay and Fe$_2$O$_3$ contents. They also observed that the adsorption of added P varied with the soils, and was generally high.

Udo (1981) evaluated phosphorus forms, adsorption and desorption in selected Nigerian soils, he reported that Langmuir adsorption isotherms gave two distinct Linear curves indicating two population of adsorbed sites. The subsoils had higher capacity than their corresponding surface soils.

Some work carried out in the laboratory (Udo and Uzu, 1972) using Chang and Jackson (1957) fractionation procedure showed that most of the added P to soils was extracted with NH$_4$F and 0.1N NaOH and a little or none appeared in the 0.5N H$_2$SO$_4$ fraction. This they said indicated that most of the added P was transformed mainly into Al-P and Fe-P and little or not into Ca-P.

Mkwunye (1977) reported low P buffering capacities for soils of Samaru in the Northern Nigerian Savanna. Ayodele and Agboola (1981) evaluated the phosphorus fixation capacity of tropical savanna soils of Western Nigeria. They observed that the fractional recovery (FR) which is the proportion of added P that was recoverable correlated with some soil physical and chemical properties at various incubation periods. At day 1, FR
correlated negatively and significantly with percent organic matter, clay, and Fe and Al oxides. Correlation of FR with organic matter decreased with time, and after 84 days, it remained constant but was significant throughout the experimental period. Correlation with pH was positive but not significant, probably due to the low variability of pH in the soils as against FR in the soils at each incubation time. Correlation with percent clay remained negative and significant throughout.

There was little change in the correlation between day 1 and 7, after which correlation remained almost the same. Correlation with Fe and Al oxides were highly significant and showed a remarkable increase between days 1 and 7, after which correlations did not change with time. At day 1, Al oxides were more highly correlated with FR than Fe oxides. The contents of clay and organic matter in soils at this initial period, however, tend to dictate the amount of fixed P and were more significantly correlated. As the time increased, the influence of the clay and organic matter decreased, while relationship to Fe and Al oxides became more significant, this suggests a predominantly influence in fixation probably because of increased precipitation reactions.

Omoregie (1998) in his study of soils from sub-humid and semi-arid zones of Nigeria observed a significant correlation between available P in soils with pH and clay content. High P fixation has also been reported in the acid sand soils of southern Nigeria by many researchers (Uzu and Udo, 1972, Osodeke et al., 1993, Osodeke and Kamalu, 1992).

Osemwota et al. (1997) evaluated the phosphorus status in some ultisols of Edo State of Nigeria. Available P was observed to correlate significantly and positively with pH while total P was negatively and significantly correlated with pH and positively and significantly correlated with percent silt.

CONCLUSION
The mechanism of P retention in Nigerian soils appeared very complex and is influenced by a number of factors. A proper understanding of this mechanism is imperative for judicious P fertilizers usage in Nigerian soils.

REFERENCES


