Phosphorus Forms and Fixing Potentials of Mbaitoli Soils in Imo State, Nigeria

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***Abstract*: The study was conducted in four different locations in Mbaitoli namely; Ifakala, Umunoha, Ogwa and Orodo in Imo State Nigeria to determine different forms and levels of phosphorus in the selected soils of the area. Fifteen composite samples were collected from the top soil (0-15cm) and sub soil (15-30cm). The fifteen composite soil samples were then bulked and a sample taken from each of the location giving a total of four representative samples. The representative soils were analyzed for physical and chemical properties. Total and Organic phosphorus were determined by standard laboratory procedure while inorganic phosphorus forms by fractionation. The macronutrients Nitrogen (N) and Potassium (K) were high low (0.220 % and 0.23mg/kg) and the pH is acidic (4.50). Available phosphorus ranged from 42.70 to 48.50 mg/kg with a mean of 46.25mg/kg while the organic phosphorus content ranged from 42.17 to 46.62mg/kg with a mean of 44.49mg/kg, total phosphorus content ranged from 102.7 to 113.71mg/kg with a mean of 108.48mg/kg. Total phosphorus and available phosphorus were very high in the soil of the study area and were in the following order; Fe-P>Al-P>Ca-P>occluded phosphorus.**

***Keywords*: Phosphorus, Fixing, Mbaitolu, Imo, Nigeria**

I. INTRODUCTION

The problem of nutrient supply and availability in the soil had continued to threaten productivity and food availability in low fertility soils. The problem becomes critical when supplied nutrient element becomes unavailable to plant as a result of much soil dynamism. The problem further worsens soil fertility and productivity when the nutrient element in question is essential for plant growth and development.

Phosphorus (P) is one of the major elements and it is second in importance to nitrogen in terms of nutrient requirement for plants, and for increased crop and food production in most tropical soils. The phosphorus problem in soil fertility according to (Brady and Weil, 2004) is three folds. First, the total phosphorus level of soils is low, usually not more than one-tenth to one fourth that of Nitrogen and one twentieth that of potassium. Second, the phosphorus compounds, commonly found in soil are mostly unavailable for plant uptake often because of highly soluble phosphate. Third, soluble sources of phosphorus such as fertilizers and manures added to the soil are fixed.

The factors that hinders levels of available phosphorus in soils helps to account for the low crop productivity.

In soils of the humid tropics, phosphorus deficiency has been found to be widely spread. In Nigeria, according to (Sobulo, 1983) responses to phosphorus application has been encountered in all ecological zones. Onwudike and Edoziem (2020) discovered varying levels of available P and other forms in rhizosphere of ground, okra and bean (*Phaseolus vulgaris*). This low availability of phosphorus in the tropical soils is attributed to the nature of the chemical form of soil phosphorus and high content of oxides of Fe and Al which are associated with high phosphorus fixation. Therefore, water soluble phosphatic fertilizer when added to the soil do not remains so. This also resulted in many forms of P existing- Organic P (Avai P) and Inorganic P-Al-P, Fe-P, Ca-P, Occl-P, Org. P. The inorganic phosphorus exists in the decreasing order of occluded P, iron bound p (Fe-P), Aluminum bound P (Al-p) and calcium bound P (Ca-p). Of all the forms of P, Available form is very important to farmers because of its importance in the soil solution, been the site for soil- plant-root interphase. The study was conducted to determine the forms and levels of P as well as physicochemical properties of the soils of the study areas.

II. MATERIALS AND METHOD

2.1. Site Description

The study was conducted in four (4) areas of Mbaitoli agro-ecological area of Imo State. Imo State is strategically located in the heart of the south eastern part of Nigeria. Mbaitoli has the following coordinates 5.5828^0 N, 7.0283^0 E

2.1.1. Sampling Techniques

When visiting the sites, proper measures were taken by using the appropriate materials and methods. The materials used were polyethene bags, auger, marking tape, maker and paper, gloves, rain boot.

2.1.2 Soil sampling method/ experimental procedures:

Fifteen composite soil samples were collected from the top soil (0-30cm). The fifteen composite soil samples were then bulked and a sample taken from each of the location given a total of four representative samples. The representative samples were used for the physical and chemical properties (routine analysis) determination and the contents of various forms of phosphorus in the soils. The samples were collected from Ifakala, Umunoha, Ogwa and Orodo in Imo State Nigeria

2.2 Soil Preparation for Analysis

The soil samples were air-dried at room temperature. They were gently crushed and passed through a 2-mm mesh sieve. A small portion of each sample were crushed with a mortar and passed through 0.5mm sieve for some analysis such as organic carbon, total nitrogen, total phosphorus and organic phosphorus.

2.2.1 Laboratory Analysis

The physicochemical analysis of the soil were carried out as follows:

2.2.2 Particle Size Distribution

Particle size analysis for the determination of percentage sand, silt and clay fraction was carried out using hydrometer method as describe by Bouyoucous (1962) and the textural classes were determined from the United State Department of Agriculture (USDA) soil textural triangle.

2.2.3 Soil pH

Soil pH was determined by the electrometric method as describe by Brady and Weil (1990). A glass electrode testronic digital pH meter was used for the measurement. The soil pH was determined only in water. Water gives the pH of soil in its natural state.

2.2.4 Total Nitrogen

This was determined by Microkejedal distillation method (Bremmer and Malvaney, 1982)

2.2.5 Phosphorous.

Available phosphorous was extracted with acid fluoride using Bray 1 and Bray 2 method (Murphy and Riley (1962) method, Total P was extracted by the perchloric acid digestion method (Jackson, 1994) and the organic form by the ignition method as described by Legg and Black (1955). Inorganic P was sequentially fractionated using the procedure outlined by Chang and Jackson (1957) to exclude the occluded forms. Phosphorus in each extract was determined colorimetrically by blue colour method of Murphy and Riley (1962).

2.2.6 Organic Carbon

Organic carbon was determined according to the method of Wackley and Black as modified by (Allison, 1982).

2.2.7 Total Exchangeable Acidity

Exchangeable Al^{3+} and H^{+} were determined by titrimetric method after extraction with 1.0 N KCL (Mclean, 1982).

2.2.8 Exchangeable Bases (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+})

The exchangeable cations were extracted from the sample using 1N Ammonium Acetate at pH 7. Exchangeable Na^{+} and K^{+} in solution was determined using flame photometer, while exchangeable Ca^{2+} and Mg^{2+} were determined using EDTA titration method as described by (Faniran and Areola, 1978).

2.3 Statistical Analysis

The data were analyzed using descriptive statistics and correlation coefficient by Martin and Andrew (2007) and results discussed in line with established critical levels of P distribution and forms of P.

III. RESULTS AND DISCUSSION

The result of phosphorus levels in selected soils of Imo State is shown in Table 1.

3.1.1 Available Phosphorus

The content ranged from 42.70 to 48.50mg/kg with an average of 46.25 and the highest level occurring in Ogwa. Based on the critical level of 15mg/kg, 100% of the selected soils were rich in available phosphorus (Table 1). Available phosphorus was generally high, thus indicating high phosphorus fertility of the selected Imo State soils. Total P, Al-P, Fe-P, pH and Na were positively and significantly correlated with available phosphorus with "r" values of 0.68**, 0.66**, 0.62**, 0.63** and 0.55* respectively (Table 3) and (Table 4).

3.1.2. Organic Phosphorus

Organic phosphorus ranged from 42.17 to 46.62 mg/kg with an average mean of 44.49mg/kg, the highest value occurring in Orodo and the least value occurring in Ogwa. Amhakhian and Semwota (2012) reported that organic phosphorus varies within each geological formation and between the between the geological formation based on their parent materials. Effective cation exchange capacity (ECEC), Calcium, Magnesium and Base Saturation were positively and significantly correlated with organic phosphorus with "r" values of 0.62**, 0.61**, 0.6** and 0.57* respectively (Table 3).

3.1.3. Inorganic Phosphorus

The distribution of various forms of inorganic phosphorus in the soils studied are shown in (Table 1). The content of Al-P varied from 3.39 to 5.66mg/kg with mean value of 4.74mg/kg. Al-P was positively and significantly correlated with Fe-P and Ca-P with "r" value of 0.7** and 0.90*** respectively. The Fe-P content ranged from 4.11 to 7.11mg/kg with mean of 5.40. Fe-P was positively and significantly correlated Ca-P, pH, K and Na with "r" value of 0.86**, 0.55*, 0.92*** and 0.71** respectively. The Ca-P content ranged from 3.15 to 4.85mg/kg with mean of 3.90mg/kg. Ca-P content was low in Ifakala and Umunoha but high in Ogwa and Orodo. From the mean value of Ca-P, it was observed that the Ca-P is generally low. Lindsay and Moreno (1960) reported the preferential formation of Ca-P relative to Al-P neutral in acidic soils. Occluded P content of the soils ranged from 3.20 to 4.02mg/kg with a mean of 3.71mg/kg, the lowest value occurring in Ifakala and the highest values occurring in Umunoha. Occluded P was positively and significantly correlated with sand with "r" value of 0.68**. Occluded P was generally observed to be low and contributed very little to total P. Amhakhian and Osemwota (2012) reported that the relative amounts of inorganic P fractions had been used to assess the extent pedogenetic processes.

Table 1: Phosphorus Forms of Selected Soils of Imo State

Location	Available P (mg/kg)	Al-P (mg/kg)	Fe-P (mg/kg)	Ca-P (mg/kg)	Occl-P (mg/kg)	Org. P (mg/kg)	Total P (mg/kg)
Ifakala	47.30	4.52	4.11	3.15	3.20	44.26	106.54
Umunoha	42.70	3.79	4.23	3.26	4.02	44.9	102.9
Ogwa	48.50	4.98	7.10	4.33	3.68	42.17	110.76
Orodo	46.50	5.66	6.14	4.85	3.94	46.61	113.71
Mean	**46.25**	**4.74**	**5.40**	**3.90**	**3.71**	**44.49**	**108.48**
STD	**2.51**	**0.79**	**1.47**	**0.83**	**0.37**	**1.84**	**4.74**

STD= Standard Deviation

The H-P was more in amount than Al-P which in turn were greater than Ca-P and Occluded P. the abundance were in the following order: Fe-P=Al-P>Ca-P>Occluded P. This is in line with Ibia and Udo (1993) who reported that the relative abundance of the active inorganic P fraction decrease in that order.

3.1.4 Total Phosphorus

Table 2: Physicochemical Properties of Selected Soils Imo State

Location	% Sand	% Silt	% Clay	Textural Class	pH H_20	Av. P	%TN	%OC	%OM	BS	Ca^{2+} $Cmol_c$ /kg	Mg^{2+} $Cmol_c$/kg	K^+ $Cmol_c$ /kg	Na^+ $Cmol_c$ /kg	ECEC $Cmol_c$/kg
Ifakala	68.80	12.00	19.20	SL	4.50	47.30	0.224	2.12	3.78	78.93	3.60	2.81	0.20	0.09	8.35
Umunoha	79.80	9.00	11.20	SL	4.30	42.70	0.238	2.26	3.89	83.72	4.00	2.41	0.22	0.06	7.86
Ogwa	81.80	7.00	11.20	SL	4.51	48.50	0.221	2.30	3.81	81.22	3.20	2.40	0.26	0.12	7.24
Orodo	74.80	7.00	18.20	SL	4.70	46.50	0.206	2.26	3.81	83.96	3.60	2.80	0.23	0.17	7.98
Mean	**76.30**	**8.75**	**14.8**		**4.50**	**46.25**	**0.220**	**1.72**	**3.82**	**81.96**	**3.60**	**2.61**	**0.23**	**0.11**	**7.86**
STD	**5.80**	**2.36**	**4.35**		**0.16**	**2.51**	**0.008**	**1.011**	**0.04**	**2.37**	**0.33**	**0.23**	**0.25**	**0.47**	**0.46**

* Legend: STD = Standard Deviation, % = Percentage, OC = Percentage Organic Carbon, OM = Organic matter, TN = Total Nitrogen, AL = Aluminum, Ca = Calcium, Mg = Magnesium, K= Potassium, Na = Sodium, ECEC = Effective Cation Exchange Capacity, BS = Base Saturation, Av. P = Available Phosphorus, H_20 = Water.

The total phosphorus values ranged from 102.9 to 113.71mg/kg with a mean of 108.48mg/kg. In Table 3, total phosphorus contents of the soils were generally high indicating the high phosphorus fertility of the soils. This is in agreement with Enwezor (1977) who reported that phosphorus content of some tropical soils has been attributed to apatite content of the soil forming minerals. The observed differences in total phosphorus values between the soils could also be attributed to parent materials of the soils maturity (Enwezor, 1977).

Table 3: Correlation between Forms of P and Chemical Properties

	Av. P	Occ. P	Org. P	Total P	Al-P	Fe-P	Ca-P	pH	OC	OM	TN	Ca	Mg	K	Na	ECEC	BS
Av.P	1.00																
Occ. P	-0.59	1.00															
Org. P	-0.46	0.39	1.00														
Total P	0.68**	0.04	0.15	1.00													
Al-P	0.66**	0.03	0.25	0.99***	1.00												

Fe-P	0.612**	0.25	-0.32	0.80**	0.72**	1.00											
Ca-P	0.43	0.42	0.21	0.93***	0.80**	0.86**	1.00										
pH	0.64**	-0.90	0.36	0.01	0.98***	0.55*	0.79**	1.00									
OC	-0.75	-0.35	-0.80	0.30	-0.63	-0.78	-0.29	-0.73	1.00								
OM	-0.89	0.77**	0.15	-0.58	-0.62	-0.26	-0.24	-0.70	0.23	1.00							
TN	-0.63	0.88**	-0.38	0.34	-0.97	-0.53	0.78**	-1.00	0.83**	0.69**	1.00						
Ca	-0.95	0.38	0.61**	-0.68	-0.62	-0.80	-0.53	0.53	-0.16	0.70**	0.50*	1.00					
Mg	0.29	-0.45	0.60**	0.38	0.50*	-0.24	0.12	0.67**	-0.62	-0.67	-0.69	0.18	1.00				
K	0.38	0.41	-0.49	0.51*	0.39	0.92***	0.67**	0.19	0.00	0.64**	-0.16	0.65**	0.69**	1.00			
Na	0.55*	0.16	0.34	0.77**	0.99***	0.71**	0.93***	0.96***	-0.84	-0.51	-0.96	-0.52	0.47	0.40	1.00		
ECEC	-0.25	0.40	0.62**	-0.26	-0.13	-0.79	-0.45	0.79**	-0.25	-0.22	-0.12	0.55*	0.79**	-0.96	-0.14	1.00	
BS	-0.60	0.98***	0.57*	0.62**	0.12	0.20	0.46	0.35	-0.51	0.69**	-0.41	0.43	-0.26	0.29	0.27	-0.24	1.00

* Significant at 5% level of probability ** Significant at 1% level of probability *** Significant at 0.1% level of probability

3.2. The Physical Properties Of The Soil

From Table 2, the soil texture of the selected area are all "sandy loam" which indicates high soil fertility statues suitable for agriculture purposes. The result showed that all the soil samples have a high percentage of sand with highest value occurring at Ogwa (81.80%) and lowest value occurring at Ifakala (68.80%), with a mean value of 76.30%. the high sand content of these soils shows the evidence of soils formed on a coastal plain sand area with relative high percent of sand.

The clay content ranged from 11.20 to 19.20% with a mean value of 14.20%. The silt content of soils of selected areas were generally low ranging from 7.00 to 12.00%. the silt/clay ration was less than one (<1) in all the sites, this agreed with the work done by Brady and Weil (1999) that soil having low silt/clay ration of <1 indicates a ferratic pedogenesis.

3.*3 Chemical Properties of Soil*

3.3.1 Total Nitrogen

Nitrogen content ranges from 0.206% to 0.238% with a mean of 0.220. The highest occurring value was found in Umunoha and lowest occurring in Orodo as shown on Table 2.

3.3.2 Soil pH (H_20)

Table 4: Correlation Coefficient Forms of Phosphorus

	Av. P	Occ. P	Org. P	Al-P	Fe-P	Ca-P	Total P
Av. P	1.00						
Occ. P	-0.59	1.00					
Org. P	-0.46	0.39	1.00				
Al-P	0.66**	0.03	0.25	1.00			
Fe-P	0.62**	0.25	-0.32	0.72**	1.00		
Ca-P	0.42	0.42	0.21	0.90***	0.86**	1.00	
Total P	0.69*	0.04	0.15	0.99***	0.80**	0.93***	1.00

** Significant at 1% level of probability *** Significant at 0.1% level of probability Av. P= Available Phosphorus, Occ. P = Occluded Phosphorus, Org. P = Organic Phosphorus, Al-P= Aluminum Phosphorus, Fe-P = Iron Phosphorus, Ca-P = Calcium Phosphorus and Total P = Total Phosphorus

The soil pH values ranged from 4.30 to 4.70 with a mean of 4.50. In Table 2, this however depicted the acidic nature of the soils of southeastern, Nigeria. (Udo, 1980), the acidic nature may also be attributed to the strong chemical weathering and leaching of nutrient characterized by humid tropical soils. Soil acidity is one of the principal factors affecting nutrient availability when low, major nutrients (N,P,K) will be limiting and thus cannot affectively promote yield of crops if it is not corrected.

Table 5: Correlation Coefficient Phosphorus Forms with Particle Size Distribution

	Av. P	Occ. P	Org. P	Al-P	Fe-P	Ca-P	Total P	Sand	Silt	Clay
Av. P	1.00									
Occ. P	-0.59	1.00								
Org. P	-0.46	0.39	1.00							
Al-P	0.66**	0.03	0.25	1.00						
Fe-P	0.62**	0.25	-0.32	0.72**	1.00					
Ca-P	0.42	0.42	0.21	0.90***	0.86**	1.00				
Total P	0.69*	0.04	0.15	0.99***	0.80**	0.93***	1.00			
Sand	-0.19	0.68**	-0.40	-0.00	-0.13	0.54*	0.30	1.00		
Silt	-0.10	-0.74	0.02	-0.66	-0.54	-0.84	-0.85	0.74**	1.00	
Clay	0.31	-0.51	0.55*	0.34	0.46	-0.26	0.64**	-0.93	0.45	1.00

* Significant at 5% level of Probability ** Significant at 1% level of probability *** Significant at 0.1% level of probability

3.3.3 Base Saturation

The base saturation mean value of more than 50% showed the soil is fertile as shown in (table 2). The high values of base saturation in the selected areas is an evidence of high fertility. Base saturation showed significant difference at (p-0.05) in the soils.

3.3.4 Sodium

Sodium content were generally low and had no significant differences. Its values ranged from 0.06 to 0.17 $Cmol_c/kg$ with a mean value of 0.11.

3.3.5 Potassium

There were significant levels of potassium. Thus ranges from 0.20 to 0.26, with mean value of 0.23.

IV. CONCLUSION

The result showed that the soils in Mbaitoli LGA in Imo State differ in their Available phosphorus and levels were well above critical limits when compared with established Critical standard. Other forms of P were present too, and their concentrations were high. These levels were not good for agricultural purposes, because the more P is high in other forms other than Available P, there is an indication that the soil has P fixing potentials. This assertion may be ignored in these locations because the levels of Available forms of P are good enough. This is an indication that other soil properties such as organic matter content and pH are at their best. The high available P signifies low P fixing potentials of the soils. Also, various phosphorus forms correlated with available phosphorus indicates 99% of the soil in the location were rich in available phosphorus. Available P is of great importance. Phosphorus is an essential nutrient for crop production in the tropics and every arable soil of the world. Its deficiency will result to low yield and consequently low agricultural production. Management practices concerning phosphorus element should be implored for effective yield and profitability of farmers. Since it was observed from the study that the soil from the four selected locations were 99% rich in available phosphorus, the four location namely: Ifakala, Umunoha, Ogwa and Orodo be continued to use for Agricultural purpose without P application but also recommend routine plant test for phosphorus levels in order manage fertilizer and soil fertility policies for optimum crop production.

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