MERIT RESEARCH JOURNALS
www.meritresearchjournals.org

Merit Research Journal of Agricultural Science and Soil Sciences (ISSN: 2350-2274) Vol. 2(8) pp. 096-103, August, 2014
Available online http://www.meritresearchjournals.org/er/index.htm

Original Research Article

Determination of phosphorus fixing capacities and residual values of soils of Akwa Ibom State, Nigeria

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Abstract

This study was conducted to evaluate phosphorus fixing capacities and residual values in soils of Akwa Ibom state, for effective and efficient P fertilizer recommendation. Soil samples were collected based on parent material in the study area (coastal plain sands, beach ridge sands, sandstone/shale, and river alluvium). In each of the parent material, soil sample were collected from three representative locations at a depth of 0-20cm with the aid of soil auger. A total of 12 soil samples were generated for analysis. Treatment solutions containing 0, 20, 40, 80 and 160 mg/l were prepared from KH_2PO_4. 20 ml portions of the treatment solutions were added to 20g of the soil samples in a cup and mixed thoroughly for effective mixing of the phosphorus solution with the soil and allowed to dry. The cups were carefully covered and allowed to stand for 1, 7, 30, 90 and 180 days respectively. The soil samples were kept moist with deionized water at weekly intervals and covered for the duration of incubation. At the set days, 20 ml of Bray P-I extractant was used to extract plant available phosphorus in the soil samples. The phosphorus in the extract was determined using the Murphy and Riley method (1962). The study revealed that the mean organic matter contents in the study areas were as follows: Fresh river alluvium (4.5%) > coastal plain sand (3.0%) > sandstone/shale (2.0%) > beach ridge sands (1.9%). Mean clay content was as follows: Fresh river alluvium (13.15%) > coastal plain sand (9.82) > sandstone/shale (7.80%) > beach ridge sands (4.87%). Mean soil pH in KCl were as follows: Fresh river alluvium (5.1) < beach ridge sands (5.2) < sandstone/shale (5.3) < coastal plain sand (5.4). The amount of P recovered at different incubation periods increased with increasing level of P addition. The proportion of added P recovered declined with increase in incubation period in all the soil types in the study area. Soils of fresh river alluvium had the highest P fixing ability while breach ridge sands soil had the lowest fixing ability. The trend is as follows: fresh river alluvium > coastal plain sand soils > sandstone/shale > beach ridge sand soils. Sandstone/shale soils had the highest residual values of added P (1.1 mg/kg) while beach ridge sands soils had the lowest residual values (0.6 mg/kg). The trend is as follows: sandstone /shale (1.1) > coastal plain sands soils (0.9) > fresh alluvium (0.7) > breach ridge sands soils (0.6). Split application of P fertilizer is recommended for soils in the study area because of formation of non-available form of P with long period of incubation.

Keywords: Keywords: Residual value of P, P fixing capacity, incubation period

INTRODUCTION

Phosphorus (P) is an essential component of cell membranes, plant genetic material and of energy storage and transfer systems for chemical reactions in plant cells. Early plant growth is particularly dependent on P because of the needs for rapid cell division and expansion. The primordia for future stems, roots, leaves, flowers and seed are produced very early in plant growth, so P deficiency during early growth of germinating seedlings and plants can greatly reduce yield potentials of crops and pastures.

Wide spread deficiencies of phosphorus have been reported as a major constraint to crop production in South-eastern Nigeria due to over cultivation and insufficient replenishment of lost P from soils (Nnoke, 1980 and Dyboh, 1999). A major loss leading to phosphorus deficiency in these soils was attributed to phosphorus fixation by sesquioxides. According to Osodeke and Kamalu 1992; Ibia and Udo 1993; Sharawat *et al*., 2001a; Osodeke, 2000, Abekoe and Sharawat 2001, 2003 and Osodeke and Ubah, 2005, highly weathered soils of the humid tropics rich in 1:1 clay minerals (kaolinite clays) and high content of sesquioxides are not only low in phosphorus but the applied soluble phosphorus is converted into forms not readily available to crops and as such limit crop production and productivity.

In Nigeria, the desired increase in crop yield from P fertilizer use has not been attained due to many reasons among which is lack of appropriate fertilizer recommendation. Fertilizer use is mostly based on blanket fertilizer application (Aduayi 1984; Agbede 2009), while fertilizer recommendation derived from soil testing programme has its limitations in that it does not consider the amount of nutrient fixed by the soil and the soil residual value of the nutrient. Literature revealed that nutrient immobilization occurs when fertilizer is applied to soil system, in that plants utilize a fractional amount of phosphorus provided through fertilization. Research results show that plants make use of 10-30% of P applied while substantial amount of applied P are fixed in the soil (Kacar and Katkat, 1997; Brandy and Weil, 1999). Such nutrients may not be absolutely made available to the crops for which they are meant unless the soil equilibrium is maintained to satisfy the fixation complex. Therefore, for fertilizer recommendation to have positive and practical impact on the crop grown, such fixed amount of nutrients and soil residual value of the nutrient should be evaluated. Information relating to P fixing capacities and residual values are inadequate on soils of Akwa Ibom State. Therefore, the objectives of this study were to evaluate the phosphorus fixing capacities and residual values on soils of Akwa Ibom State, Nigeria for effective and efficient P- fertilizer recommendation.

MATERIALS AND METHODS

Description of the study area

The study was conducted in 2kwa Ibom State, Nigeria. Akwa Ibom State lies within latitudes $4^0 30^|$ and $5^0 30^|$N and longitudes $7^0 30^|$ and $8^0 20^|$ E. The area is underlain mainly by sandstone/shale, coastal plain sands, beach ridge sands and alluvial parent materials (Petters *et al*., 1989; Usoro and Akpan, 2010). No portion of the study area exceeds 175m above sea level. The climate is humid tropical with annual rainfall of about 2500 - 3000 mm with 1-3 dry months in the year. Mean annual temperature varies between 27-28^{0}C with relative humidity of 75-80 % (Petters *et al*., 1989; Usoro and Akpan, 2010).

Field sampling

Soil samples were collected based on parent materials in the study area. There are four major parent materials in the study area. There are coastal plain sands, beach ridge sands, and sandstone / shale, and river alluvium. In each parent material, soil sample were collected from three representative locations at depth of 0-20 cm using soil auger. A total of 12 soil samples were generated for laboratory analysis.

Procedure and laboratory analysis

The method of Ayodele and Agboola (1981) was used for the study. Five sorption treatment solutions containing 0, 20, 40, 80 and 160 mg/l were prepared from KH_2PO_4. Twenty grams (20g) of soil sample was weighed into labeled 50ml plastic incubation cups and 20 ml portions of each of the five treatment prepared solution were added to each of the soil samples in the cups. The contents in the cups were mixed thoroughly for effective mixing of the phosphorus solution with the soils and allowed to dry. The cups were carefully covered and allowed to stand for 1, 7, 30, 90 and 180 days respectively. The soil samples were kept moist with deionized water at weekly intervals and covered for the duration of incubation. At the set days, 20 ml of Bray P-I extractant was used to extract plant available phosphorus in the soil samples. The phosphorus in the extract was determined using the Murphy and Riley method (1962).

Parts of the soil samples were air dried and thereafter crushed and sieved through 2 mm sieve for the following analysis: Particle size distribution was analyzed using hydrometer method. (Gee and Bauder, 1986). Soil pH was determined in water 1:2.5 soil: water ratio in INKCl using pH meter with glass electrode as described by Thomas (1996). Exchangeable cations were extracted with neutral NH_4OAc. Calcium and Magnesium were determined in the extract by EDTA titration as described by Udo *et al.,* (2009). Potassium and Sodium by the use of flame photometer.Organic carbon was determined by wet-oxidation method as described by Nelson and Sommers (1998). Available phosphorus was determined by Murphy and Riley method (1962) after extraction by Bray P-I extractant. Effective cation exchange capacity

Table 1. Soil physical and chemical properties of the study area

Soil properties	Coastal plain sand	River alluvium	Sandstone/shale	Beach ridge sand
Sand (%)	77.55 ± 4.2	64.22 ± 20.0	75.55 ± 9.0	89.46± 3.2
Silt (%)	9.80 ± 1.2	13.15 ± 9.9	7.82 ± 2.3	4.87 ± 1.2
Clay (%)	12.65 ± 3.1	22.63 ± 23.2	16.63 ± 11.0	5.67 ± 2.1
Texture	Loamy sand	Sandy loam	Loamy sand	Sand
pH (water)	6.0 ± 0.09	6.0 ± 0.1	6.0 ± 0.1	6.0 ± 0.01
pH (Kcl)	5.4 ± 0.3	5.1 ± 0.04	5.3 ± 0.3	5.2 ± 0.02
EC (ds/m)	0.15 ± 0.2	0.50 ± 0.7	0.07 ± 0.03	0.12 ± 0.2
Total N (%)	0.073±0.02	0.11± 0.006	0.05 ±0.02	0.05 ±0.02
Org. Matter (%)	3.0 ± 0.5	4.5 ± 0.1	2.0 ± 0.6	1.9 ± 0.8
Av. P (mg/kg)	17.9 ± 10.7	6.92± 6.2	12.6± 1.6	8.52 ± 5.9
Ex. Ca (cmol/kg)	5.7 ± 1.4	6.7 ± 3.1	5.4 ± 0.5	3.7 ± 2.0
Ex. Mg (cmol/kg)	1.9 ± 1.5	2.3 ± 1.0	1.6 ± 0.4	1.5 ± 1.5
Ex. Na (cmol/kg)	0.04 ± 0.006	0.06 ± 0.06	0.05 ± 0.006	0.04 ± 0.01
Ex. k (cmol/kg)	0.08 ± 0.06	1.0 ± 0.06	0.07 ± 0.06	0.07 ± 0.06
Ex. A (cmol/kg)	1. 7 ± 0.09	2.9 ± 1.7	1.2 ± 0.09	1.8 ± 0.09
ECEC (cmol/kg)	9.1 ± 1.6	12.0 ± 5.1	8.3 ± 0.9	6.9 ± 2.7
Base sat (%)	81.45 ± 3.3	75.15 ± 10.6	85.75 ± 1.6	70.54 ± 11.2

Ec = Electrical conductivity, **Ex. A** = Exchangeable acidity

(ECEC) was obtained by the summation of the exchangeable cations and exchangeable acidity as described by summer and Miller (1992).

Data analysis and interpretation

The linear regression that expresses the relationship between fractional recovery (FR) and rate of element addition was calculated for all the soils at the different incubation period as: Y = a + b x where

Y = Phosphorus extracted from each soil type at a given rate of addition and time of incubation.

a = intercept of regression line corresponding to extractable P at zero application and at day 1.

b = slope of regression line representing fractional recovery (FR) which is the proportion of the added P recovered at a particular period of time of incubation.

X = the rate of phosphorus added (mg/l).

Toobtain the residual values of P

The relationship FR = -Kt + C was used, where:

FR = Fractional Recovery

-K = Slope of regression line

t = Time in days (incubation days)

C = Intercept which corresponds to FR at day 1 and at zero. Fractional Recovery values were plotted against time and the slope of the regression represent the residual values of phosphorus in the study area.

RESULTS AND DISCUSSION

Physical and chemical properties of soils of the study area

The mean soil physical and chemical properties of the study area are presented in Table 1. The dominant soil texture in the surface soil of coastal plain sand soil is loamy sand with mean sand fraction of 77.55 ± 4.2 %, silt fraction of 12.63 ± 3.1% and clay fraction of 9.82 ± 1.2 %. In sandstone / shale soil, the dominant soil texture was also loamy sand with mean sand fraction of 75.6 ± 9.0 %, silt fraction of 16.6 ± 11.0 % and clay fraction of 7.8 ± 2.3 %. In river alluvium, the dominant soil texture is sandy loam with mean sand fraction of 64.22 ± 20.0 %, silt fraction of 22.63 ± 23.1 % and clay fraction of 13.15 ± 9.9 %. In beach ridge soil, the dominant soil texture is sandy with mean sand fraction of 89.47 ± 3.2 %, silt fraction of 5.66 ± 2.1 % and clay fraction of 4.87 ± 1.2 %. The variation in texture reflects the differences in parent materials (Enwezor *et al*., 1990).

The mean soil reaction in water was 6.0 ± 0.09 in coastal plain sands soils, 6.0 ± 0.1 in fresh river alluvium, 6.0 ± 0.09 in sandstone/shale and 6.0 ± 0.01 in beach ridge sand soils. The soil reaction in the study area was moderately acidic. The mean soil reaction measured in KCl solution was 5.4 ± 0.3 in coastal plain sands soils, 5.1 ± 0.04 in river alluvium, 5.3 ± 0.3 in sandstone/shale soils and 5.2 ± 0.01 in beach ridge sands soils. In all the soil types, pH measured in water was higher by about 1-2 units than the respective pH values measured in KCl solution. The low soil pH with KCl determination indicates the net negative charges of the soils. According to Anon (1993), high soil acidity with KCl determination showed the presence of potential acidity and weatherable minerals.

The mean organic matter content of coastal plain sands soils was 3.0 ± 0.5 %, river alluvium was 4.5 ± 0.1 %, sandstone/shale was 2.0 ± 0.6 %, and beach ridge sands soils was 1.9 ± 0.8 %. Fresh river alluvium had the highest mean organic matter, followed by coastal plain sands while beach ridge sands soils had the lowest

Table 2a. Regression equations of the relationship between phosphorus extracted and different rates of phosphorus added (0, 20, 40, 80 and 160 mg/l) at different incubation periods (days of incubation 1-180 Days) Y = a + bx

Parent material	Rep.	1 day			7 days			30 days			90 days			180 days			Range (mg/kg)	Mean (mg/kg)
		a	b	R^2	a	b	R^2	a	b	R^2	a	b	R^2	a	b	R^2		
CPS	1	20.068	0.077	0.9518	24.567	0.055	0.8794	29.361	0.1682	0.9787	33.323	0.117	0.886	15.513	0.118	0.735		
	2	18.995	0.096	0.882	25.691	0.067	0.9595	37.02	0.149	0.9684	52.025	0.114	0.8388	20.941	0.062	0.8275		
	3	24.005	0.089	0.8625	33.693	0.034	0.9105	51.701	0.115	0.9718	63.815	0.116	0.8887	24.34	0.058	0.7673		
	Mean		0.087			0.052			0.144			0.116			0.079		0.052-0.14	0.10
RV	1	9.9195	0.098	0.9836	14.037	0.132	0.9868	21.804	0.240	0.9719	31.76	0.158	0.9925	9.690	0.076	0.9837		
	2	8.7163	0.063	0.9664	7.265	0.129	0.8445	9.166	0.053	0.9006	7.417	0.079	0.9962	11.254	0.027	0.9019		
	3	0.168	0.010	0.9838	0.619	0.080	0.7284	0.004	0.006	0.957	0.147	0.003	0.9544	0.282	0.002	0.8283		
	Mean		0.06			0.11			0.10			0.08			0.04		0.04 -0.11	0.08
SS/S	1	4.386	0.081	0.8683	5.971	0.141	0.787	2.597	0.192	0.9411	2.674	0.133	0.978	0.190	0.140	0.9858		
	2	20.001	0.089	0.6885	18.055	0.110	0.9839	31.844	0.147	0.8941	69.12	0.111	0.9547	16.048	0.131	0.8049		
	3	9.242	0.081	0.7953	11.709	0.122	0.9197	18.148	0.205	0.9552	19.09	0.123	0.9443	10.464	0.065	0.8292		
	Mean		0.084			0.124			0.18			0.122			0.112		0.084-0.18	0.12
BRS	1	1.906	0.097	0.9891	2.233	0.135	0.9414	2.332	0.275	0.9251	1.592	0.249	0.9835	2.137	0.120	0.9779		
	2	1.019	0.052	0.993	1.017	0.074	0.9847	0.262	0.146	0.996	0.835	0.098	0.9874	0.137	0.056	0.9651		
	3	1.707	0.079	0.9891	1.653	0.135	0.9405	2.023	0.132	0.9405	4.585	0.124	0.9101	1.582	0.110	0.9905		
	Mean		0.076			0.115			0.184			0.157			0.095		0.076-0.184	0.13

a = Intercept of regression line corresponding to extractable P at zero P addition. SH = Sandstone / Shale, BRS = Beach ridge sands, RV = River alluvium CPS = Coastal plain sands,
b = the slope of regression line represents fractional recovery (FR)
x = the rate of P added (mg/l)
y = Amount of P recovered

Table 2b. Amount of P extracted by Bray P-1 extractant at different rates of P addition over different time periods in soil sample

Parent material/Location	Rate of P added (mg/l)	Incubation Period (Days) Amount of P Extracted from soil sample (mg/kg)				
		1	7	30	90	180
Coastal Plain Sand	0	19.63	24.43	29.30	30.86	8.76
(CPS)	20	20.95	25.33	30.86	33.62	21.77
1	40	23.17	25.81	36.92	43.94	22.87
	80	28.09	31.22	44.96	51.03	27.37
	160	31.52	32.59	55.23	57.27	32.06
2	0	19.45	27.44	35.54	49.83	20.47
	20	20.35	28.21	38.96	51.75	21.91
	40	20.53	28.69	45.50	60.63	22.27
	80	30.25	31.09	50.01	63.87	28.93

Table 2b. Continue

	160	33.26	36.26	59.91	68.13	29.53
3	0	22.13	33.08	52.29	63.03	21.29
	20	23.17	34.06	52.69	64.53	27.21
	40	25.93	35.68	55.83	65.83	28.31
	80	31.58	37.16	62.79	69.21	29.59
	160	38.36	38.54	69.52	70.36	32.66
River Alluvium (RV)	0	9.43	15.31	20.11	31.76	9.96
1	20	11.93	15.79	25.57	35.60	10.96
	40	15.07	18.31	32.06	36.74	13.27
	80	16.87	25.15	45.20	45.26	14.77
	160	25.81	35.29	58.05	56.91	22.15
	0	8.22	6.36	8.22	7.02	10.93
2	20	9.73	7.68	9.67	9.25	11.89
	40	11.35	9.49	13.21	10.63	12.01
	80	14.95	10.09	13.45	14.17	14.31
	160	18.13	11.41	17.29	19.99	15.11
3	0	0.12	0.18	0.06	0.14	0.19
	20	0.30	0.96	0.08	0.18	0.36
	40	0.66	1.20	0.12	0.24	0.52
	80	1.08	1.36	0.54	0.42	0.42
	160	1.74	1.68	0.90	0.54	0.60
Sandstone/ Shale	0	4.56	3.84	0.72	4.80	1.50
	20	5.10	5.58	4.98	5.46	2.34
1	40	6.18	13.27	7.50	13.27	4.38
	80	14.23	24.67	13.39	18.49	12.00
	160	16.09	24.85	47.90	41.36	22.69
	0	15.79	18.37	35.18	70.24	14.03
2	20	20.75	22.27	35.30	71.68	14.53
	40	28.75	38.54	35.54	73.30	26.59
	80	29.66	47.54	39.38	75.46	29.83
	160	31.88	80.50	58.05	88.06	34.52
	0	8.01	12.19	16.21	16.33	7.98
3	20	9.19	12.73	22.81	22.57	12.07
	40	13.27	15.07	25.21	25.99	15.43
	80	19.93	25.27	39.14	29.60	16.49
	160	20.11	29.89	48.86	37.70	19.75
Beach Ridge Sand	0	1.44	1.50	0.60	1.98	0.78
(BRS)	20	4.20	4.86	5.64	5.58	4.68
1	40	5.34	6.24	11.11	14.11	7.62
	80	10.63	16.69	22.51	18.67	13.15
	160	16.99	22.33	42.14	42.38	20.41
	0	1.38	1.20	0.54	1.32	0.54
2	20	1.92	2.04	1.92	3.36	0.78
	40	3.00	4.74	5.22	3.72	3.00
	80	4.86	6.24	11.65	8.22	3.66
	160	9.55	13.09	23.17	16.87	9.42
3	0	1.86	1.44	1.62	2.22	1.92
	20	3.48	3.72	4.56	6.60	4.08
	40	5.04	5.04	5.58	10.87	4.80
	80	7.09	9.73	16.14	18.00	10.87
	160	14.71	13.09	21.79	22.33	19.09

organic matter content. The trend is as follows: Fresh river alluvium (4.5%) > coastal plain sand (3.0%) > sandstone/shale (2.0%) > beach ridge sands (1.9%). The high organic matter content of the fresh river alluvium could be attributed to the seasonal deposition of the organic material from plant debris during flooding and the slow rate of decomposition during flooded periods. Generally, organic matter was high in river alluvium, moderate in coastal plain sands and low in both sandstone shale and beach ridge sands.

The mean available P was 17.9 ± 10.7 mg/kg in the coastal plain sand soils, 6.9 ± 6.2 in fresh river alluvium, 12.7 ± 1.6 mg/kg in sand stone /shale and 8.5 ± 5.8 mg/kg in breach ridge soils. The low mean value of available P in river alluvium could be attributed to the reaction of P with Al and Fe which is high in the soil and convert the P into insoluble form (Nathan, 2002).

In coastal plain sand soils, mean exchangeable Ca was 5.7 ± 1.4 cmol/kg, exchangeable Mg was 1.9 ± 0.5 cmol/kg, exchangeable Na was 0.04 ± 0.006 ccmol/kg and exchangeable K was 0.08 ± 0.006 cmol/kg. In fresh river alluvium, the mean exchangeable Ca was 6.7 ± 3.1 cmol/kg, exchangeable Mg was 2.3 ± 1.0 cmol/kg, exchangeable Na was 0.06 ± 0.001 cmol/kg and exchangeable K was 0.1 ± 0.006 cmol/kg. In sandstone/shale soils, mean exchangeable Ca was 5.4 ± 0.5 cmol/k, exchangeable Mg was 1.6 ± 0.4 cmol/kg, exchangeable Na was 0.05 ± 0.006 cmol/kg, and exchangeable K was 0.07 ± 0.01cmol/kg. In beach ridge sands soils, mean exchangeable Ca was 3.6 ± 2.0 cmol/kg, exchangeable Mg was 1.5 ± 0.5 cmol/kg, exchangeable Na was 0.04 ± 0.01cmol/kg and exchangeable K was 0.07 ± 0.006 cmol/kg. Exchangeable Ca and Mg were higher in river alluvium than other soil types. These higher values could be attributed to the release of organic forms of Ca and Mg from the organic matter (Ambeager, 2006). Na and K were generally very low in the study area.

Mean effective cation exchange capacity (ECEC) of coastal plain sands soils was 9.1 ± 1.6 cmol/kg, fresh river alluvium was 12.0 ± 5.1 cmol/kg, sandstone/shale soils was 8.3 ± 0.9 cmol/kg, while beach ridge sands soils was 6.9 ± 2.7 cmol/kg. The trend is as follows: Fresh river alluvium (12.0%) > coastal plain sand (9.1%) > sandstone/shale (8.3%) > beach ridge sands (6.9%). Fresh river alluvium had the highest ECEC while beach ridge sand soils had the least ECEC. The trend is similar to that of organic matter. This shows that organic matter contribute significantly to the total ECEC of the soil in the study area. Organic matter is the store of essential elements, hence the higher the organic matter levels, the higher the soil ECEC and buffering capacity (Ogbodo, 2011).

Phosphorus fixing capacities of soils of the study area

Values of phosphorus extracted from each soil type at a given rate of P addition (0, 20, 40, 80 and 160 mg/l) and time of incubation (1, 7, 30, 90 and 180 days) were plotted and the slope of the regression represent the fractional recovery which is the proportion of the added P recovered at a particular incubation period. The unrecovered amount is considered to be fixed (Table 2). The mean fractional recovery of added P in beach ridge sand soils was 0.13 $mgkg^{-1}$ (13.0 %), sandstone/shale soils was 0.12 $mgkg^{-1}$ (12.0%), fresh river alluvium was 0.08 $mgkg^{-1}$ (8.0%) while coastal plain sand soils was 0.10 $mgkg^{-1}$ (10.0%). The study shows that beach ridge soils had the highest mean recovery of applied P over different incubation periods (13.0%) while fresh river alluvium had the least mean recovery of added P (8.0 %). The trend is as follows: beach ridge sand soil (13%) > sandstone / shale (12 %) > coastal plain sand soil (10%) > fresh river alluvium (8%). This is an indication that fresh river alluvium had the highest P fixing capacity while beach ridge sand soils had the least fixing ability. The high P fixing ability of fresh river alluvium at various incubation periods could be attributed to the high levels of organic matter and high content of Al / Fe (lower pH) in the soil. The high content of Fe/Al results in conversion of soluble P to insoluble Al / Fe phosphate, as well as high rate of adsorption (labile P). This finding is in agreement with the report of Ibia *et al.*, (2009) that fresh river alluvium soils had the highest P fixing capacity among the soils of Akwal bom State.

It was also observed that that the amount of P recovered decreased with the length of incubation and increase with increase in amount added (Table 2). In beach ridge sands soils, the P recovered declined from 18.4 % at 30th day of incubation to 9.54 % at the 180th day. In fresh river alluvium, the mean P recovered declined from 10 % at 30th day to 4.0 % at 180th day. In coastal plain sands soils, the mean P recovered declined from 14.4 % on the 30th day to 7.9 % at the 180th day of incubation. In sandstone/shale soils, P recovered declined from 15.6 % on the 30th day to 11.2 % on the 180th day. This shows that as incubation period increases, the amount of phosphorus recovered decreases. The result is in agreement with that of Warren (1992), who observed that availability of phosphorus to plant decreased with an increase in contact time and attributed it to the formation of less soluble phosphorus product with time. Andersen *et al.*, (1990) and Larsen and Gunary, (2001) also observed a reduction in yield, as well as fertilizer uptake by rye grass as reaction time increased. They attributed it to the formation of non-available form of P with time.

Residual value of applied p in soils of the study area

Fractional Recovery values were plotted against incubation period (FR = -Kt + C) and the slope of the regression represent the residual values of phosphorus (Table 3). The mean residual value of P of sandstone/shale soils was 1.1mg/kg, coastal plain sands soils was 0.9 mg/kg, fresh river alluvium was 0.7mg/kg while beach ridge sands soils was 0.6 mg/kg. The trend is as follows: sandstone /shale (1.1) > coastal plain sands soils (0.9) > fresh alluvium (0.7) > breach ridge sands soils (0.6). Sandstone/shale had the highest residual mean value while fresh alluvium and beach ridge sands had the lowest residual mean value of applied P. Low residual value in beach ridge sands soils could be attributed to high leaching rate of added P due to the sandy texture of the soils while fresh alluvium is due to high fixing capacity of the soil.

Table 3. Regression equation of the relationship between fractional recovery of P and different incubation periods (1-180 days) FR= -Kt + C

Parent material	Rep.	1 day			7 days			30 days			90 days			180 days			Range	Mean mg/kg
		-kt	c	r^2	-kt	c	r^2	-kt	c	r^2	-kt	c	r^2	-kt	c	r^2		
CPS	1	-2.548	27.262	0.0757	1.033	23.447	0.0872	1.753	25.283	0.0864	1.837	31.023	0.0941	2.576	34.006	0.0941		
	2	-1.743	21.717	0.1145	2.666	24.238	0.103	3.542	24.896	0.1066	3.014	31.788	0.0492	2.441	38.095	0.0492		
	3	0.827	33.883	0.0269	3.855	28.762	0.1194	3.491	31.843	0.979	2.807	37.645	0.0306	2.042	43.762	0.0306		
	Mean	-1.155			2.518			2.929			2.552			2.353			-1.155-2.929	0.89
RV	1	1.751	12.061	0.091	1.787	14.609	0.0728	1.483	18.641	9.0488	1.591	24.677	0.0177	1.43	35.352	0.0177		
	2	0.608	6.326	0.3025	0.589	7.877	0.3827	0.246	10.6	0.0769	0.28	12.55	0.0149	0.254	15.624	0.0149		
	3	0.01	0.108	0.0919	-0.066	0.574	0.0921	-0.144	0.96	0.284	-0.206	1.402	0.8669	0.342	2.118	0.8669		
	Mean	0.7897			0.77			0.528			0.555			0.675			0.528-0.7897	0.66
SS/S	1	-0.516	4.632	0.193	-0.516	4.632	0.193	-0.36	10.	0.0191	-1.064	19.749	0.1224	2.972	21.66	0.1224		
	2	4.835	16.217	0.1064	3.701	21.799	0.065	3.044	31.412	0.0642	2.826	35.896	0.0062	1.284	54.75	0.0062		
	3	0.408	10.92	0.0243	1.56	11.194	0.1502	1.524	14.422	0.1565	-0.255	26.851	0.0082	0.709	29.135	0.0081		
	Mean	1.576			1.582			1.403			0.519			1.640			0.5187-1.640	1.1
BRS	1	-0.084	1.512	0.0554	0.168	4.488	0.1872	1.243	2.933	0.1504	0.702	14.22	0.057	2.689	20.783	0.1177		
	2	-0.156	1.464	0.3428	0.096	2.292	0.0275	-0.102	4.242	0.0254	-0.042	7.052	0.0004	0.352	13.364	0.0093		
	3	0.09	1.542	0.2277	0.408	3.264	0.2669	0.481	4.931	0.0899	0.942	10.822	0.1081	0.93	17.152	0.2129		
	Mean	-0.05			0.16			0.540			0.534			1.324			-0.05-1.324	0.64

FR = -Kt + C
Where: C= Intercept of regression line corresponding to residual value at zero applied P.
-K = the slope of regression line representing the residual value.
t = Time in day of incubation.

CONCLUSION

The study revealed that the amount of P recovered at different incubation periods increased with increasing level of P addition. The proportion of added P recovered declined with increase in incubation period in all the soil types in the study area. Soils of fresh river alluvium had the highest P fixing ability while beach ridge sands soil had the lowest fixing ability. Sandstone/shale soils had the highest residual values of added P while beach ridge sands soils had the lowest residual values. Therefore, for effective P-fertilizer application and utilization, split application of P fertilizer is recommended for soils in the study area because of formation of non-available form of P with long period of incubation.

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