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DETERMINATION OF PHOSPHORUS AND POTASSIUM FIXATION CAPACITIES AND FERTILIZER FACTORS IN SOILS OF THREE COCOA GROWING AREAS OF NIGERIA

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ABSTRACT

Ogunlade MO, Ibiremo OS, Ipinmoroti RR, Iloyanomon CI, Aikpokpodion PE (2011) Determination of phosphorus and potassium fixation capacities and fertilizer factors in soils of three cocoa growing areas of Nigeria. *J. Soil Nature* 5(1), 11-16.

Phosphorus and Potassium fixation capacities in soils of three cocoa growing regions-Ibadan, Owena and Ikom in Nigeria were determined by evaluation of P and K fixation capacities of the soil as well as some physical and chemical properties. Results indicated that the fixation capacities of the soil for P was in the order of Ikom (54%) > Ibadan (13%) > Owena (3%). It was similar for K in the order of Ikom (68%) > Ibadan (51%) > Owena (48%). The fertilizer factor determined for the soils also followed similar order with highest fertilizer factor obtained for P (2.53) and K (6.4) in Ikom location soils and P (1.15) and K (4.01) in Ibadan location soils. Phosphorus and potassium fixation correlated positively with clay, organic carbon, Mn and Fe contents of the soil while pH, sand and silt were negatively correlated with P and K. The fertilizer factors for P and K obtained for the soils in this study is made to take care of any fixed amount of P and K applied when fertilizer recommendation is made in the study area. Fertilizer recommendation that takes these fertilizer factors into consideration is expected to impact positively on the resultant crop yield since provision is already made for the fixed nutrients via the fertilizer factor.

Key words: *fertilizer factor, phosphorus fixation, potassium fixation*

INTRODUCTION

In Nigeria, the desired increase in crop yield from P and K fertilizer use has not been attained due to many reasons among which is lack of adequate 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. Literature revealed that nutrient immobilization occurs when fertilizer is applied to soil system, in that plants utilize a fractional amount of phosphorus and potassium 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 1965; 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 should be evaluated via fixation study.

The study aimed at determining the proportion of added nutrient that is not immobilized over time (Fractional Recovery-FR) and the amount of P and K needed to raise the soil test value by 1 unit (Fertilizer Factor- FF).

MATERIALS AND METHODS

Fixation studies were conducted to determine the fractional recovery values and the fertilizer factors for P and K. The study was carried out by collecting soil samples from cocoa plantations in Cocoa Research Institute of Nigeria (CRIN) headquarters, Ibadan and two of CRIN substations- Owena in Ondo state and Ajassor in Cross River state and FR and FF determined using the procedure outlined by Hunter (1975). The soils of Ibadan and Owena are underlain by metamorphic rocks of the basement complex, the majority of which are of Pre-Cambrian age (Smyth and Montgomery, 1962), and the soils are classified as typic Kanhaplustalf and typic Haplustalf respectively. The soil of Ikom location is principally derived from basalt under humid tropical forest vegetation (Eshett 1987), and the soils are classified as typic Tropohumult (Soil Survey Staff 2006).

Stock solution was prepared by dissolving 6.15g of KH_2P_{04} in 1500ml of distilled water in a 2 litre flask and made up to 2 litres with distilled water. Five (5) sorption treatment solutions (A- E) were prepared by diluting 5, 10, 20, 40 and 80ml of the stock solution to 100ml (Table 1). 2.5g soil was weighed into labeled 50ml plastic cups in tray racks and added 2.5ml of each of the five sorption solutions accordingly, while 2.5ml of distilled water was added to the control in three replicates.

Table 1. Concentrations of P and K in sorption treatment solutions

Sorption treatment solutions	Vol. of stock solution diluted to 100 mls	Conc. of P in sorption treatment solution mg/kg	Conc. of K in sorption treatment solution(cmol/kg)	Quantity of soil in the cup (g)	Vol. of treatment sol. added to the soil (ml)
A	5	35	0.11	2.5	2.5
B	10	70	0.22	2.5	2.5
C	20	140	0.45	2.5	2.5
D	40	280	0.90	2.5	2.5
E	80	560	1.80	2.5	2.5

Hunters (1975)

The set up was covered and then incubated for 1, 7 and 42 days. The treated soil samples and the control in the cups were watered to keep them moist through out the period of incubation. At these set days, 3 cups each of the treated soils and control were extracted with 1.0 NH40AC (pH 7.0), while another three cups each of treated soils and control were extracted with Bray P solution for K and P determination respectively. K in the extract was determined using flame photometer and P by colorimeter and their FR and FF were then determined.

The linear regression that expresses the relationship between FR and rates of element addition was calculated for all the soils at the different incubation periods as:

$Y = a + b\,x$ …… equation 1

Where Y = P or K extracted in mg/kg or cmol/kg
X = Rate of P or K addition
a = P or K extracted at zero addition
b = Fractional recovery

Fertilizer Factor was determined using the relationship:

$$\text{Nutrient required} = \frac{\text{Nutrient added at rate R}}{\text{Nutrient recovered at rate R- Nutrient in untreated soil sample}} \quad \text{eq.2}$$

Soils Analysis

The physical and chemical properties of the soils (Table 2) showed that the soils were slightly acidic with the N, P and K values grossly below the critical levels of 0.9mg/kg, 10mg/kg and 0.3cmol/kg respectively estimated to be ideal for cocoa (Egbe *et al.* 1989). This implies that for optimum crop productivity in the three soils, there will be need for fertilizer application to cater for the three critical nutrients required by cocoa. Extractable Mn and Fe as well as clay content were considerably higher for Ikom location soil compared to both Owena and Ibadan location soils. This may not be unconnected to the parent materials of Ikom location soil.

Table 2. Initial physical and chemical properties of soils at the three locations

Soil Properties	Ibadan	Owena	Ikom
pH	6.00	5.80	5.05
Organic carbon (g/kg)	10.10	11.30	20.02
N (g/kg)	0.77	0.85	0.49
P (mg/kg)	4.11	5.23	8.40
K (cmol/kg)	0.22	0.18	0.11
Ca (cmol/kg)	4.45	4.19	0.48
Mg (cmol/kg)	1.23	1.42	0.41
Na (cmol/kg)	0.13	0.11	0.13
Exchangeable acidity (cmol/kg)	0.73	0.82	2.20
Zn (mg/kg)	5.56	6.55	82.99
Cu (mg/kg)	6.40	5.37	66.18
Mn (mg/kg)	18.90	13.80	186.22
Fe (mg/kg)	5.83	6.62	120.84
Sand (g/kg)	600	720	672
Silt (g/kg)	240	180	154
Clay (g/kg)	160	100	174
Texture	Sandy loam	Sandy loam	Clayey loam

RESULTS AND DISCUSSION

Phosphorous

Fractional Recovery (FR) and the Fertilizer Factor (FF) for available phosphorus showed an increase in the amount of P recovered with increase in the amount of P added to the soil (Tables 3 and 4). It was observed that the amount of P recovered decreased with the length of incubation period. This corroborated the findings of Mallikarjuna *et al.* (2003). The FR therefore declined with time which was an indication of fixation of added P. The phosphorus FR mean values in the soils were 0.87, 0.97 and 0.46 for Ibadan, Owena and Ikom respectively. At day 1, the average P recovered was highest at Owena and least at Ikom. The P fractional recovery follows similar trend at day 7 and 42 after application (Table 3). The mean FR of (0.87, 0.97 and 0.46) for Ibadan, Owena and Ikom respectively indicated the fixation of about 13, 3 and 54% of the added P for Ibadan, Owena and Ikom location soils respectively. The fixation capacity in Ikom location soil for added P was highest compared to the other locations.

The mean values of fertilizer factor obtained for phosphorous were 1.15, 1.12 and 2.53 for Ibadan, Owena and Ikom location soils respectively. Within the period under consideration, the mean phosphorus FF of Ikom soil was highest. This implies that the fixation capacity of Ikom soil is higher than that of the two locations of Owena and Ibadan. It showed that the higher the fixation capacity of the soil, the higher the fertilizer factors that were determined.

Table 3. Fractional Recoveries (FR) for different rates of added P (mg/kg) at Ibadan, Owena and Ikom location soils

Location	Concentration of P (mg/kg) applied	Fractional Recovery of P at different incubation periods (days)			Mean
		1	7	42	
Ibadan	35	1.37	1.15	0.85	
	70	1.07	1.00	0.91	
	140	0.94	0.91	0.37	
	280	0.84	0.81	0.78	
	560	0.77	0.63	0.67	
	Mean	0.99	0.90	0.72	0.87
Owena	35	1.59	1.38	0.92	
	70	1.01	1.00	0.87	
	140	0.90	0.96	0.90	
	280	0.95	1.00	0.92	
	560	0.80	0.73	0.70	
	Mean	1.05	1.01	0.86	0.97
Ikom	35	0.76	0.70	0.71	
	70	0.55	0.59	0.55	
	140	0.35	0.53	0.50	
	280	0.23	0.30	0.30	
	560	0.21	0.34	0.33	
	Mean	0.42	0.49	0.48	0.46

Table 4. Fertilizer Factor for P in the soils of Ibadan, Owena and Ikom

Location	Concentration of P (mg/kg) applied	Fertilizer Factor at different incubation periods (days)			Mean
		1	7	42	
Ibadan	35	0.73	0.87	1.17	
	70	0.93	0.99	1.10	
	140	1.06	1.10	1.31	
	280	1.19	1.23	1.28	
	560	1.20	1.59	1.50	
	Mean	1.04	1.15	1.27	1.15
Owena	35	0.63	1.72	1.09	
	70	0.99	1.00	1.14	
	140	1.11	1.04	1.10	
	280	1.05	0.99	1.09	
	560	1.25	1.38	1.42	
	Mean	1.01	1.03	1.33	1.12
Ikom	35	1.32	1.42	1.41	
	70	1.83	1.71	1.80	
	140	2.88	1.89	2.01	
	280	4.29	3.29	3.30	
	560	4.81	2.95	3.07	
	Mean	3.03	2.25	2.32	2.53

Potassium

The amount of extracted K decreased with length of incubation (Table 5). The mean FR and FF for K were 0.49, 0.52 and 0.32 for Ibadan, Owena and Ikom location soils respectively. This implied that about 51, 48 and 68% of added K in Ibadan, Owena and Ikom location soils respectively were fixed. This shows that the fixation capacity of Ikom location soil for K was highest compared to Ibadan and Owena location soils. This was similar

to what obtained for P fixation. The mean fertilizer factor values for K were 4.01, 4.03 and 6.4 for Ibadan, Owena and Ikom location soils respectively (Table 6). This suggests that FF for K in Ibadan and Owena soils were 37% lower than that of Ikom soil, thus, showing that the fertilizer factors determined for K at Ibadan and Owena were similar.

Table 5. Fractional Recoveries (FR) for different rates of added K (cmol/kg) at Ibadan, Owena and Ikom location soils

Location	Concentration of K (cmol/kg) applied	Fractional Recovery of P at different incubation periods (days)			Mean
		1	7	42	
Ibadan	0.11	1.27	1.27	1.09	
	0.22	0.68	0.64	0.55	
	0.45	0.33	0.36	0.33	
	0.90	0.19	0.17	0.19	
	1.80	0.11	0.11	0.11	
	Mean	0.52	0.51	0.45	0.49
Owena	0.11	1.36	1.27	1.09	
	0.22	0.73	0.68	0.59	
	0.45	0.38	0.36	0.53	
	0.90	0.20	0.19	0.19	
	1.80	0.10	0.11	0.10	
	Mean	0.55	0.52	0.50	0.52
Ikom	0.11	0.73	0.82	0.73	
	0.22	0.41	0.50	0.41	
	0.45	0.22	0.24	0.22	
	0.90	0.11	0.14	0.12	
	1.80	0.06	0.07	0.07	
	Mean	0.31	0.35	0.31	0.32

Table 6. Fertilizer Factor for K in the soils of Ibadan, Owena and Ikom

Location	Concentration of K (cmol/kg) applied	Fractional Recovery of P at different incubation periods (days)			Mean
		1	7	42	
Ibadan	0.11	0.79	0.79	0.92	
	0.22	1.47	1.57	1.83	
	0.45	3.00	2.81	3.00	
	0.90	5.29	6.00	5.29	
	1.80	9.47	9.00	9.00	
	Mean	4.00	4.03	4.01	4.01
Owena	0.11	0.73	0.79	0.92	
	0.22	1.38	1.47	1.69	
	0.45	2.65	2.81	3.00	
	0.90	5.00	5.29	5.29	
	1.80	10.00	9.47	10.00	
	Mean	3.95	3.97	4.18	4.03
Ikom	0.11	1.38	1.22	1.38	
	0.22	2.44	2.00	2.44	
	0.45	4.50	4.09	4.50	
	0.90	9.00	6.92	8.18	
	1.80	18.00	15.00	15.00	
	Mean	7.06	5.85	6.3	6.4

Relationship of some soil characteristics and fixation of P and K in the studied soils

The correlation coefficients between some soil characteristics and fixation of P and K in the soils of the study areas for clay, organic carbon, iron and manganese were positively correlated with both P and K fixation though not significantly (Table 7). The values showed that the higher the clay, organic carbon, Fe and Mn in the studied soils, the higher were the fixation of both P and K. In similar studies, Thomazi *et al.* (1990) reported that iron

oxides and clay were the main factors contributing to P fixation in soils. Beckett, 1970 reported that among the various factor affecting K fixation, soil clay constitutes the most important one. The higher correlation between P fixation and Fe with Mn might be due to the formation of insoluble Mn and Fe phosphates. The correlation coefficient between organic carbon and P fixation (0.96) was quite high probably due to the formation of phosphohumic compounds (Dolui and Gangopadhyay, 1984). The soil pH, sand and silt were negatively correlated with P and K fixation. This is consistent with the findings of Kanwar and Grewal (1990) who found that the lower the pH, the more available the metallic ions especially Mn, Fe and Al and these elements then combine with soluble P to form insoluble compounds. Naidu *et al*. (1990) explained the increase in P-fixation with decrease in the pH through interactions between added P, negative charges and the electrostatic potential in the plain of sorption. Negative correlation of sand contents of the studied soils with P and K fixation was in line with the findings of Woodruff and Kamprath (1965) and Silbel and Cimrin (2006) who reported that sandy ultisols retain much less phosphorus than clayey ultisols of similar mineralogy.

Table 7. Relationships between some soil properties and fixation of P and K in the studied soils

Some Soil Properties	P Fixation	K Fixation
Clay	0.78ns	0.75ns
Silt	-0.60ns	-0.63ns
Sand	-0.07ns	-0.03ns
pH	-0.93ns	-0.94ns
Organic carbon	0.96ns	0.97ns
Fe	0.98ns	0.99ns
Mn	0.99ns	0.99ns

ns = not significant

SUMMARY AND CONCLUSION

Ikom location soil has highest capacity for P and K fixation out of the three soils studied. This might be due to higher Fe, Mn, clay and Organic carbon content of this soil compared to the other two locations. The fertilizer factors for P and K obtained for the soils in this study will take care of the fixed amount of the applied nutrients (P and K) when fertilizer recommendation is made in the study area. More K than P was fixed in the three location soils and that accounts for higher fertilizer factor for K in the study areas. Fertilizer recommendation that takes into consideration these fertilizer factors will impact positively on the resultant crop yield since provision is made for the fixed nutrients via the fertilizer factor.

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REFERENCES

Aduayi EA (1984) Effects of long term ammonium sulphate fertilization on the pH and elemental distribution at three soil depths of South Western Nigerian soil. *Communication in Soil Science and Plant Analysis*. Vol. 15, 461-475.

Agbede OO (2009) Understanding Soil and Plant Nutrition, 1st. ed. Salman Press Nig. Ltd, Keffi- Nasarawa.

Beckett PHT (1970) Fixed K and the residual effects of K fertilizers. Potash Review Subject 16, 52th Suite:1-12.

Brandy MC, Weil Ray R (1999) The Nature and Properties of Soils, 12th ed. Prentice-Hall New Jersey.

Dolui AK, Gangopadhyay SK (1984) Fixation of Phosphate in relation to properties of some red and lateritic soils of West Bengal. *Indian Journal of Agricultural chemistry* XV11 (2), 177-182.

Egbe NE, Ayodele EA, Obatolu CR (1989) Soils and Nutrition of Cocoa, Coffee, Kola, Cashew and Tea. *In Progress in tree crop research in Nigeria*. 2nd Ed. CRIN, Ibadan. Pp 27-38.

Eshett ET (1987) The basaltic soils of SE Nigeria: properties, classification and Constraints to productivity. *Journal of Soil Science* 38, 565-571.

Hunter AH (1975) Laboratory and greenhouse technique for nutrient survey to determine the soil amendment required foor optimum plant growth. Int. Soil Fert. Ev. Imp. Project. N.C. University, Raleigh, N.C.

Kacar B (1965) Phosphorus fixation in culcurowa soils. Ann. Rep. Ankara University, Agric. Fac., 15, 158-179.

Kacar B, Katkat VA (1997) Tarimda fosfor. Bursa Ticaret Odasi Yayinlari No5.

Kanwar JS, Grewal J (1990) Phosphorus fixation in Indian soils 2nd edition. New Delhi, Indian: Indian Council of Agricultural Research.

Mallikarjuna G, Sudhir K, Srikanth K, Srinivasamurthy CA (2003) Phosphorus fixation capacity and its relationship with the soil characteristics in laterite soils of Karnataka. *Journal of the Indian Society of Soil Science* vol. 51, no 1, pp23-25.

Naidu R, Syers JK, Tillman RW, Kirkman JH (1990) Effect of liming on phosphate sorption by acid soils. *Journal of Soil Science* 41(1), 163-175.

Sibel B, Cimrin KM (2006) Determination of phosphorus fixation of the wheat- growing soils in the Lake Van Basin. *Journal of Agronomy* 5(2), 196-200.

Smyth AJ, Montgomery RF (1962) Soils and land use in Central Western Nigeria. Government. Western Nigeria: Ibadan. 265pp.

Soil Survey Staff (2006) Keys to Soil Taxonomy, 10th ed. United States Department of Agriculture, Natural Resources Conservation Services, p. 331.

Thomazi MD, Mello FAF, Arzolla S, Mello FA (1990) Phosphate fixation in soils of the piracicaba Municipality. *Revista de Agricultura* 65(1), 45-53.

Woodruff JR, Kamprath EJ (1965) Phosphorus adsorption maximum as measured by Langmuir Isotherm and its relationship to phosphorus availability. *Soil Science of America Proceedings* 29; p148-280.