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Fractional Recovery of Applied Potassium in Soils of Southeastern Nigeria

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ABSTRACT

The fractional recovery of K was assessed in three selected surface soils of southeastern Nigeria. Soils used were form on alluvium, shale, and coastal plain sands parent materials and were treated to various concentration levels of K, ranging from 0 -200mgl^{-1} prepared from KCL. The amount of K was measured at time intervals of 1, 7, 30, 90 and 180 days. Result of incubation period shows that the highest K recovered was obtained in alluvium soil while the least came from shale in the order: alluvium (0.26) > coastal plain sand (0.11) > shale (0.02). Soils developed from shale had the highest K fixing capacity (98%) while alluvium (74%) had the least. The amount of K required to increase the soil solution K value (NH_40Ac extracted) by 1mgl^{-1} (fertilizer factor) was high: coastal plain sands (166.0 cmolkg^{-1}) > alluvium (67.4 cmolkg^{-1}) > shale 55.1 cmolkg^{-1}). The fertilizer factor provides a useful index of obtaining the K fertilizer needs and these rates are recommended for these soils studied.

Keywords: Potassium, Parent Material, Fixation, Fractional Recovery, Fertilizer Factor.

INTRODUCTION

Among the major plant nutrients, potassium is the most third important in the soils, after N and P. It exists in soil in different forms as structural (mineral) non exchangeable (fixed or difficulty available), exchangeable and water – soluble forms (Dhahiwal *et al*., 2006, Ravichandran and Sriramachandrasekharan 2011) and the potassium forms are in dynamic equilibrium. Potassium (K) fixation and release in soil, depend on factors such as soil types, amount of K added in the soil, contact time, soil reaction and prevailing mechanisms of K reactions. Fixation of potassium by soils controls its availability to plants in various degrees held. (Ano, 2003, Agbede, 2009, Bangroo *et al*, 2012). Methods of determining the capacity of soils to retain or fix potassium vary considerably among soils. Fractional recovery (FR) which involves the measurement of applied K in the soil by means of soil test method used in determining K availability is also used in establishing a basis for K recommendations. The fraction of added K not recovered is regarded as the K fixed or retained by soil when known rates of K are applied to the soil and allowed to equilibrate after which NH_4OA_Cextracted value is determined at different time intervals. Fractional recovery approach has been used by Agboola (1982) to establish Fertilizer factor (Ff) from which K fertilizer recommendations could be based. Sufficient information on the fixation and recovery of applied K in soils of Eastern Nigeria is lacking. The present study therefore examines the fixation and recovery of K in three different soils (coastal, plain sands, alluvium and shale) with a view to establishing a basis for fertilizer recommendations.

MATERIALS AND METHODS

Location of study/Field Studies

Soil samples from three parent materials in Southeastern Nigeria were collected from 0 – 15cm depth for the study. The area of study spans over: Alluvium [Itu - 5^0 10^1N and 7^0 59^1E], Shale [Odukpani - 5^0 7^1N and 8^0 20^1E] and Coastal Plain Sands [Umudike - 5^0 28^1N and 7^0 32^1E]. These soils were air-dried at room temperature, crushed and sieved to obtain particles less than 2.0mm.

Analytical Procedure

Particle size distribution was determined by the Bouyoucos hydrometer method (Klute, 1986). Soil pH was determined using pH meter with glass electrode in 1:2.5 soil/water ratio. Organic carbon was determined by wet oxidation method (Nelson and Sommers (1996), while total N was determined by the method of Sparks (1996). Exchangeable bases were extracted using 1M NH_4OA_C, K and Na in the extract were measured using flame photometry while Mg and Ca were read on atomic absorption spectrophotometer. The physico - chemical properties of the soils are shown on Table 1.

Potassium Incubation Studies

Soil samples collected from three parent materials in Southeastern Nigeria (Table 1) were used for the study. A 20ml portion of the treatment solution (potassium chloride) at five rates viz: 0, 50, 100, 150 and 200 mg/l K, was added to 20g of each soil sample in duplicate cups and allowed to stand (incubated) for 1, 7, 30, 90 and 180 days, respectively. The soils were kept moist with deionized water at weekly intervals and covered for the duration of incubation. After each incubation time, the K in soil was extracted with ammonium acetate and the value read on flame photometry to obtain available K in a set of samples. The fractional recovery (FR) of K was obtained from the relationship between the amount of K added and the amount extracted by (NH_40Ac) using the expression: $y = a + bx$. where;

y	=	potassium extracted from each soil at a given rate of addition and time of incubation;
a	=	intercept of regression line corresponding to extractable K at zero application and at day 1.
b	=	the order/trend of recovery of K from soil
x	=	the rate of K added (mg/l).

The fractional recovery determines the amount of K adsorbed as the different between K added and K extracted by ammonium acetate, while the potassium (K) fixation capacity (KFC) was obtained from the relationship;

KF C (%) = (I – FR). 100; where,
FR = Fractional Recovery at a given time of incubation.

Statistical Analysis

Analysis of Variance (ANOVA) was performed to assess the fractional recovery of K among the parent's materials using GLM Procedure (Genstat Software). Pearson Correlation matrix was performed to asses the relationship between the fractional recovery of added K and some soil properties. The test of significance was made with probability value of 0.05.

RESULTS AND DISCUSSION

Selected physico-chemical properties of the studied soils are shown in Table 1, the amount of potassium (K) recovered in the different soils studied at different time interval are shown in Table 2, and the relationship is described by regression data in Table 3. The amounts of K extracted at each time interval increased with increasing levels of K added, irrespective of the parent materials (from $0mgL^{-1}$ to $200mgL^{-1}$K addition). This observation agrees with the work of Ogunlade *et al.* (2011) that the rate of K added was directly proportional to the rate of extraction. Also the amount of K extracted after 30 days of incubation was higher than K extracted at 1, 7, 90 and 180 days, (Table 2). The reduction after 30 days of incubation could be attributed to the fixation of applied K on the surfaces of clay in the soil and these result can give a significant yield reduction.

The order of recovery of K is the b term reflected in the regression equation in Table 3. The percentage recovery is shown in Table 4. Soils which developed from alluvium had the highest recovery of K (0.26 $cmolkg^{-1}$), indicating weak affinity to retain K while shale formation had the least (0.02 $cmolkg^{-1}$) suggesting stronger affinity to retain or fixed K than alluvium. The maximum K fixation of 98% observed in shale soil was possibly due to its high content of clay [$434gkg^{-1}$] [Table 1.] The degree of fixation or release in soils depends on the amount of clay mineral and its charge density (Udo, 1982; Agbede 2009). An increase in supply of K in the soil, equilibrium will shift towards left, resulting in more fixation, due to additional K being forced into the interlatice positions (Ano, 2003) and increasing saturation of specific K fixation sites. The lower K fixation in alluvium soil could result from high organic carbon content (Table I), which caused partial saturation of K fixing sites (Rao *et al.,* 2000 and Akintokun and Owoeye 2011). Among the soil types studied alluvium had significant, ($P<0.05$) negative relationship between fractional recovery with clay content ($r = - 0.96$), coastal plain sand soils had positive relationship between fractional recovery with pH (r = 0.82) and clay (r = 0.82), while shale also had a positive correlation with clay (r = 0.90) and organic carbon content (r = 0.86).

Table 1: Selected Physico-chemical properties of the studied soils.

Soil types / Parent Material	Particle Size Sand (gkg^{-1})	Silt	Clay	pH	Organic Carbon gkg^{-1}	Total N gkg^{-1}	Exch. Bases K^{+}	Mg^{2+}	Ca^{2+} cmolkg-1	CEC
Itu (alluvium)	464	102	434	5.4	19.7	0.49	0.3	4.7	3.0	8.0
Odukpani (Shale)	648	120	232	6.1	24.4	0.61	0.2	3.8	1.5	5.5
Umudike (Coastal Plain Sand)	782	66	152	5.0	18.6	0.47	0.3	4.1	2.3	6.7

CEC = cation exchange capacity

Table 2: Amount of K extracted at different K rates of addition over different time periods in the soil samples

Parent Material/Location	Rate of K added (mgl^{-1})	Incubation Period (Days) Amount of K extracted from soil sample 1	7	30 (cmol kg^{-1})	90	180
Shale (SH) parent material (Odukpani)	0	1.17	1.42	2.66	1.44	1.21
	50	1.91	2.03	4.03	2.02	1.21
	100	3.77	2.50	4.31	2.16	1.44
	150	4.02	3.51	6.23	7.26	2.82
	200	7.16	3.57	7.08	7.32	3.40
Coastal Plain Sand parent material (Umudike CPS)	0	1.72	2.01	1.59	1.70	0.55
	50	3.15	2.11	2.00	1.90	1.19
	100	3.40	2.22	5.69	1.84	1.42
	150	3.47	2.54	5.72	2.18	1.54
	200	5.36	3.63	6.10	2.42	1.95
Alluvium (AV) parent material (Itu)	0	2.46	2.22	3.13	0.90	1.56
	50	3.15	3.18	4.05	1.99	1.70
	100	3.34	3.90	6.18	2.84	2.09
	150	3.36	4.47	6.92	5.74	2.94
	200	4.49	5.93	7.08	4.74	3.23

Table 3: Regression equation of fractional recovery of K from soil samples at different period of incubation (y=a+bx)

Time (days)

		1				**7**				**30**				**90**				**180**				
Locations	**Parent materials**	**A**	**b**	**R^2 (%)**	**r**	**a**	**b**	**R^2 (%)**	**r**	**a**	**b**	**R^2 (%)**	**r**	**a**	**b**	**R^2 (%)**	**r**	**a**	**b**	**R^2 (%)**	**r**	**MFR**
Odukpani	Shale	0.78	**0.028**	91.7	0.96	1.45	**0.012**	94.1	0.98	2.65	**0.022**	95.3	0.98	0.64	**0.034**	75.2	0.90	0.82	**0.012**	80.8	0.93	**0.02**
Umudike	Coastal Plain Sand	1.9	**0.15**	85.8	0.93	1.77	**0.07**	69.3	0.88	1.67	**0.25**	76.0	0.91	1.66	**0.03**	84.7	0.94	0.7	**0.06**	90.9	0.97	**0.11**
Itu	Alluvium	2.48	**0.13**	92.4	0.97	5.86	**0.33**	94.9	0.98	10.5	**0.40**	91.6	0.97	-6.1	**0.37**	59.8	0.84	5.27	**0.094**	87.6	0.95	**0.26**

R^2/r = Coefficient of determination
a = Intercept of regression line corresponding to extractable K at zero K addition
b = The slope of regression line represents fractional recovery (FR)
MFR = Mean fractional recovery

Table 4: Potassium fixing capacities of soils of the study area

Location	Parent materials	Soil Class (USDA)	Mean Fractional Recovery (FR) of K	Fixing capacities of K (1-FR) x 100
Odukpani	Shale	Typic Hapludult	0.02	98%
Umudike	Coastal Plain Sand	Typic Paleudult	0.11	89%
Itu	Alluvium	Rhodic Tropudults	0.26	74%

Fertilizer Factor

A useful derivation obtained from fractional recovery approach to estimating potassium fixing capacity of soils is the K Fertilizer factor (Ff). This factor is defined as the amount of K needed to increase the soil solution K by 1cmolkg^{-1}, and derived from the relationship.

Ff = Ka/Kr – Ku; where
Ka = K added at a given time
Kr = K recovered at that rate of addition
Ku = Amount of K extracted from the control

The calculated Ff values for the soils studied are presented on Table 5. The results indicated that the soil required mean value of 166.0mgL^{-1} (coastal plain sand), 67.4mgL^{-1} (alluvium) and 55.1mgL^{-1} (Shale) of K to raise the soil K solution by 1cmolkg^{-1}. The values are quite higher than those reported by Dhaliwal *et al.,* (2006) on Bechmark soil series in North Western India. These show that high fixing soil requires more K to compensate the unsaturated sits created in non-exchangeable positions. This finding agrees with the results of Ogunlade *et al.,* (2011) who reported that the higher the adsorption capacity of the soil, the higher the fertilizer factors.

Table 5: Fertilizer factor for K in the soils of the study area

Parent Materials	Concentrations of added K (mg/l)	K recovered at different rate of addition and at different incubation Period (days)			
		1	30 (cmol kg^{-1})	90	Mean
Shale	**50**	67.6	36.5	86.2	
	100	38.5	60.6	139	
	150	52.6	42.0	25.8	
	200	33.4	45.2	34.0	
	Mean	**48.0**	**46.1**	**71.3**	**55.1**
Coastal Plain Sand	**50**	35.0	122.0	250	
	100	59.5	24.4	714	
	150	85.7	36.3	313	
	200	30.1	44.3	277	
	Mean	**52.6**	**56.8**	**388**	**166.0**
Alluvium	**50**	72.5	54.3	45.9	
	100	113.6	32.8	51.9	
	150	166.7	39.6	31.0	
	200	98.5	50.6	52.1	
	Mean	**112.8**	**44.3**	**45.2**	**67.4**

CONCLUSION

The study showed that soils from alluvium had the highest K recovery, lowest fixing capacity, short lasting effect of added K; shale formation had lowest K recovery, highest fixing capacity and have longest effect of added K. The amount of K recovered at different incubation periods increased with increasing level of K added, and the added K recovered started declining at 30 days of incubation in all the soils studied. Clay and pH were identified as the active agents of fixation. These had significant negative correlations with fractional recovery. From the calculated fertilizer factor required to raise the soil K by 1cmol kg^{-1} in solutions, coastal plain sand required (166mgL^{-1}), alluvium (67mgL^{-1}) and shale (55.1mgL^{-1}). On the basis of fractional recovery, the fertilizer factor calculated are the K fertilizer requirements of these soils.

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