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Evaluation of Potassium Fixation Capacity and Residual Values in Soils of Southeastern Nigeria

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ABSTRACT

This study was conducted to evaluate Potassium fixing capacities and residual values in three selected surface soils of Southeastern Nigeria. The soils were form from Sandstone (SS), Basement Complex (BC) and Basalt (BA) parent materials and were treated to various concentration levels of K raging from 0 – 200mg/l prepared from KCl and amount of K were measure at time intervals of 1, 7, 30, 90 and 180 days. The physical and chemical properties were also assed. Results revealed that the soil had low fertility. The amount of K recovered at different incubation period increase with increase level of K added. The soils recorded the highest amount of extractable K at 30 days of incubation. Sandstone soil had the highest K fixing capacity while Basement Complex soil had the lowest fixing capacity, the trend is as follows: Sandstone (84%) > Basalt (82%) > Basement Complex (76%). Sandstone soil had the highest residual values of added K while Basaltic soil had the lowest residuals values. The trend is as follows: Sandstone (1.4mgkg^{-1}) > Basement Complex (0.59) > Basalt (0.49). The following fertilizer factor (FF) calculated as basement complex (102mg/l)>basalt (96.5mg/l) > Sandstone (62mg/l) are recommended for the soils. A contact time of 30 days is the best time to optimized the benefit of added K. Lighted liming may be done to increase PH and raise the release of K from the soils.

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

INTRODUCTION

Considering the cumulative effects of many physiological reactions in plant, Potassium has a significant role in plant grow and development. It is absorbed by plants in large amount, although total soil K content exceeds crop uptake during a growing season, in most cases only a small fraction of it is available to plant. Alias *et al* (2012) and Bangroo *et al* (2012) Potassium has been identified as one of the most limiting nutrients elements in crop production in these soils, due to it's high fixation which is attributed to factors such as, amount of K added, contact time, the nature of the fixation products and soil Physical and Chemical properties Udo (1982) and Ano (2003) One of the most significant consequences of K deficiency reflects in reduction of plant statue, leading to low yield. Potassium fixation occurs when fertilizer is added to soil and a small fraction in solution is utilized by plant while substantial amount of applied K are retained Ano (1992) and Dhaliwal *et al (*2006) such nutrient may not be available to crops, unless the soil equilibrium is maintained to satisfy the fixation complex. The mount of clay, PH, soil organic matter (SOM) hydroxide aluminum, cation exchange capacity (CEC) and fertilization are the major factors affecting the equilibrium Bangroo *et al (*2012). Residual effect of fertilizer is viewed as carry over effect on the remains after losses via leaching, crop removal, erosion and possible fixation of a previous years fertilizer inputs on the performance of the succeeding crop. Warren (1992) and Osodeke (2000). In Nigeria, the desired increase in crop yield from K 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 (Agbede, 2009) while fertilizer recommendation derived from soil testing 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. Therefore, for fertilizer recommendation to have positive impact on the crop growth, fixation Capacity and residual value of nutrient should be evaluated. Information on fixation capacity and residual values of K in soils of Southeastern Nigeria is lacking. These studies were designed to evaluate the fixation capacity and residual values of Potassium in these soils.

MATERIALS AND METHODS

Soil Sampling and Sample Preparation

Soil samples selected from three (3) Parent Materials in Southeastern Nigeria were used for the study. Samples were collected from 0 -15cm depth to represent each parent materials: Sandstone (Amaeke) located at latitudes 5^0 33 N 7^0 37^1 E Basement Complex (Akamkpa) lies within latitude 5^0 19 N 8^0 20^1 E and Basalt (Ikom) falls within Latitudes 5^0 57^1N 8^0 42^1E. These soils were air-dried and sieved through 2-mm mesh.

Analytical Procedure

Particle size distribution was determined by the Bouyocos hydrometer method (Klute, 1986) Soil PH was determined with PH meter glass electrode in 1:2.5 soil/water ratio, Organic matter by wet oxidation method (Nelson and Sommers, (1996), exchangeable bases was extracted using 1M NH_4OA_C. K and Na in the extracts were measured using flame photometry while Mg and Ca was determined by atomic absorption spectrophotometry.

Incubation Procedure

Twenty grams of soil was weighted into each of the incubation Cup as described by Agboola (1982). A solution containing 0, 50, 100, 150, and 200 mg/l K, was prepared from KCl was used for the study. A 20ml portion of the treatment solution was added to each soil in the cups and mixed thoroughly for effective mixing of the K solution with the soils and allowed to dry. The treatments were then arranged in randomized complete block design (RCBD) with the soil types representing the blocks, for each of the incubation period. The cups was 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. After each incubation time, the K in soil were extracted using ammonium acetate and determining using the flame photometry to obtain available K in soil samples.

Data analysis and interpretation

The linear regression that expresses the relationship between fractional recovery (FR) and rate of K added was calculated for all the soils at different incubation period as: 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 = Slope of regression line representing fractional recovery which is the proportion of the added K recovered at a particular period of time of incubation.
x = The rate of K added (mg/l)
Potassium fixation capacity (KFC) was obtained from the relationship KFC% = (1-FR) x 100
Where FR = Fractional Recovery at a given time. To obtain the residual values of K

The relationship FR = -Kt + C were 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 K in the study.

Fertilizer Factor (Ff) was obtained from the relationship Ff = Ka/Kr – Ku. Where: Ka – K added at a given time, Kr = K recovery at that rate of addition, Ku = Amount of K extracted

RESULTS AND DISCUSSION

Characteristics of the Studies Soils

The physical and chemical characteristics of the soil are shown in Table I, the particle size analysis showed that the soils were generally light textured, ranging from sandy loamy to sandy clay loam with sand predominating. The variation in the texture reflects the differences in parent materials as they affect water and nutrient leaching and retention as well as suitability of soils as a rooting medium (Aguilera *et al.,* 2012). The soil pH in water and KCl varies from (5.4 – 5.6) and (4.7 - 5.1), considered slightly acidic condition. This was an indicative that soils were highly weathered. Barman *et al.,* (2012) reported losses of nutrient through these medium. All the pH values in salt extract were less than those in the aqueous extract, indicating that the soils are negatively charged at their natural state Villapando and Greetz (2001). The soils are non-saline with low electrical conductivity values ranged from (0.06 ds/m) in basement complex to (0.1 ds/m) in Sandstone and Basalt. Organic matter content of the soils ranged from 2.7 to 5.0g kg^{-1} as shown in Table 1. The values were above the critical level of 2g kg^{-1} proposed by Aduayi *et al* (2002) for soils of Southeastern Nigeria. All the soil had total N below the critical level (2 g kg^{-1}) set for crop production in most soils of Eastern Nigeria Aduayi *et al* (2002) and the soils had P level lower than the critical level of 2-15 mg kg^{-1} proposed for most crops. The order of abundance of exchangeable base for the soil is Ca > mg > K > Na. all the soils had calcium levels above the critical level of 2 $Cmolkg^{-1}$ Aduayi *et al (*2002) Magnesium Mg^{2+} value fall within the critical level of 1-3 Cmolkg-1 except sandstone soil 7.7 $Cmolkg^{-1}$ which is rated very high Enwezor *et al,* (1989). The exchangeable potassium (K^t) varied from 0.1 to 2.2 Cmo/kg^{-1} as shown in Table 1. The level in all the soils fell within the critical K level for most crops in the zone (Enwezor *et al.,* 1989). The exchangeable acidity of the soils rated high above the critical levels of 2.0 $Cmolkg^{-1}$ (Njoku *et al.,* 1987). The effective cation exchange capacity (ECEC) was low in the soils (Except) in Basaltic soil. With values remaining below 12 $cmolkg^{-1}$. The low (ECEC) value showed an indication of low activity clays as indicated by Sparks (2000). The base saturation were high in all the soils except Basement Complex with moderate percentage (Enwezor *et al.,* 1987).

Table 1: Physical and Chemical Properties of the Soils

Soil Properties		Sandstone (Amaeke)	Basement Complex (Akamkpa)	Basalt (Ikom)
Sand	%	74.2	69.0	69.2
Silt	%	14.4	10.6	16.2
Clay	%	11.4	20.4	14.6
Texture		SL	SCL	SL
PH(H_20)		5.6	5.4	5.6
pH(KCL)		5.1	5.1	5.4
EC ds/m		0.1	0.06	0.1
OM	gkg^{-1}	4.8	2.7	5.0
Total N	gkg^{-1}	0.2	0.2	0.2
Av. P	mg kg^{-1}	20.0	3.0	7.3
Ex.Ca	$cmolkg^{-1}$	6.0	3.0	5.8
Mg	$cmolkg^{-1}$	2.6	1.2	3.4
Na	$cmolkg^{-1}$	0.05	0.04	0.05
K	$cmolkg^{-1}$	0.1	0.1	2.2
EA	$cmolkg^{-1}$	2.1	4.5	2.3
ECEC	$cmolkg^{-1}$	11.1	9.0	13.7
Base Saturation (%)		79.8	49.1	83.3

SL – Sandy, SCL – Sandy Clay Loam, SL – Loamy Sand, EC – Electrical Conductivity, OM – Organic Matter
Av.P – Available Phosphorous, EA – Exchangeable acidity, ECEC – Effective Cation exchange capacity

Potassium Fixing Capacities of the Studies Soils

The Potassium extracted from each soil types at a given rate of K added and time of incubation (days) were plotted and the slope of the regression represent the fractional recovery which is the proportion of the added K recovered at a particular incubation period. The unrecovered amount is considered to be fixed as shown in Table 2 and 3.

The mean fractional recovery of added K in Sandstone soil was 0.16mgkg^{-1} (16.0%), with high fixing ability (84%) and Basement Complex was 0.24mgkg^{-1} (24%) with the least fixing ability of 76% as shown in Table 3. The high K fixing capacity of these soils at various incubation periods could be attributed to the high levels of Silt and clay contents (Table I). The degree of K fixation in these medium depends on their charge density and the amount of K added. This finding is in agreement with the report of Dhaliwal *et al.,* (2006) that high amount of silt plus clay increase K fixation capacity. The highest fractional recovery of added K in soil developed from Basement Complex with the least fixing capacity as shown in Table 3 could be attributed to the 1:1 type of clay mineral present. This is because distribution of K between exchange and solution phases depends upon the amount and type of clay minerals (Sparks 2000). At low pH, the lack of K fixation is due to large numbers of H_30^+ and their ability to replace K as well, Hydroxy Al and hydroxy Fe^{3+} interlayer group also act as props to decrease K fixation. Rao *et al.,* (2000) and Sparks, (2001).The study revealed that amount of K recovered decreased with the length of incubation and increase with increase in amount added as indicated in (Table 2). In Sandstone soils the K recovered declined from (0.039) 39% at 90 day to (0.12) 12% at the 180 day of incubation. In Basement Complex and Basaltic soils the K recovered reached the peak at 30 days and declined at 90 days of incubation as shown in (Table 2). This indicated that as incubation period increase, the amount recovered decreases, the result is in lines with that of Ravichandran and Sviramachandrasekharan (2011), who observed that availability of K to plant decreased with an increase in contact time and attributed it to the formation of less soluble K product with time. Allan *et a.,* (1998) observed a reduction in yield of about 30% in alfalfa after a contact time of 12 weeks (84 days). Therefore, in the study area, a contact time of 30 days is the best time for crops to optimize the benefit of added K. it is evident that after 30 days of incubation, more of the added K is adsorbed into exchange sites. These soils had a negative relationship between fractional recovery with silt clay, organic matter and pH (soil reaction).

Residual Value of applied K in the study Soils

The results of residual K values of the soils obtained from the relationship between fractional recovery and time of incubation (FR = -kt + c) are presented in Table 4. Fractional recovery values were plotted against time and the slope of the regression represents the residual values of K (-K term). The studies revealed low residual values of K in these soils, ranging from 0.49 (Basement Complex) to 1.4 Cmolkg (Sandstone). The low values could be attributed to the high fixation of K in the soils. The result is in line with the report of Udo (1982) and Ano, (2003) that most surface soils of Southeastern Nigeria are highly fixed by these nutrient.

Table 2: Regression equation of fractional recovery of K from soils 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**
Amaeke	Sandstone	2.92	**0.125**	95.8	0.98	8.62	**0.24**	89.9	0.96	3.88	**0.26**	94.9	0.98	9.49	**0.039**	28.9	0.54	2.06	**0.12**	99.9	0.99	**0.16**
Akamkpa	Basement complex	0.50	**0.139**	98.2	0.99	4.12	**0.34**	99.8	0.99	0.72	**0.35**	99.4	0.99	0.48	**0.18**	91.2	0.96	0.34	**0.17**	99.5	0.99	**0.24**
Ikom	Basalt	2.12	**0.094**	97.0	0.98	9.54	**0.32**	89.4	0.95	8.2	**0.19**	91.6	0.96	1.54	**0.16**	87.1	0.93	3.94	**0.12**	97.0	0.98	**0.18**

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 3: Potassium Fixing Capacities of Soils

Location	**Parent material**	**Soil Class (USDA)**	**Mean Fractional (FR) of K**	**Fixing capacities of K 1 – FR X 100**
Amaeke	Sandstone	Typic Tropaquents	0.16	84%
Akamkpa	Basement Complex	Typic Tropudult	0.24	76%
Ikom	Basalt	Typic Dytropept	0.18	82%

Table 4: Regression equation of the relationship between fractional recovery of K and period of incubation (1 – 180 days). FR = -Kt + C.

Location	Parent material	C	-K	R^2	Residual value ($cmolkg^{-1}$)
Amaeke	Sandstone	3.37	0.0142	14.7	1.4
Akamkpa	Basement Complex	1.44	0.0059	72.6	0.59
Ikom	Basalt	1.43	0.0049	4.9	0.49

C = Intercept, -K = slope of regression line, t = Time in days

From the study, a fertilizer factor (Ff) which is the amount of K needed to raise the soil solution K by 1 $Cmolkg^{-1}$ was calculated. The result indicated that basement complex required 102.1mg/l > basalt 96.5mg/l > Sandstone 62 mg/l. (Table 3) The highest fertilizer factor of Basement Complex soil could be attributed to 1:1 type of clay dominating in the soil (Enwezor, 1990). Potassium adsorption and desorption is more rapid in external surface sites of organic phases of 1:1 clay mineral soil and are readily accessible for exchange than interlayer sites of 2:1 clay minerals (Spark, 2001). Due to the rapid adsorption of solution K to the external surface, it require large amount of applied K to raise the soil solution K. This finding is in agreement with the result of Ogunlade *et al* (2011) who reported that the higher the adsorption capacity of K in the soil, the higher the fertilizer factor.

Table 5: Fertilizer factors 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) ($cmolkg^{-1}$) 1	30	90	Mean
Sandstone	**50**	46.7	108.7	31.8	
	100	52.9	138.9	56.8	
	150	60.5	38.5	79.8	
	200	65.6	12.0	58.8	
	Mean	56.4	74.5	56.8	**62.6**
Basement complex	**50**	61.0	24.4	128	
	100	63.7	31.9	227	
	150	85.2	46.7	278	
	200	80.0	58.7	143	
	Mean	72.5	40.4	193	**102.1**
Basalt	**50**	87.7	41.3	94.3	
	100	79.4	40.7	157	
	150	7.8	56.4	259	
	200	62.7	69.9	202	
	Mean	59.4	52.1	178	**96.5**

CONCLUSION AND RECOMMENDATIONS

The study revealed that the soils were moderately acidic and light textured. Most of the soils were low in nutrients and salt free. From the incubation experiment Basement Complex soil had the highest K recovery, lowest fixing capacity and short lasting effect of added K. Soils from Sandstone parent materials had lowest K recovery, highest fixing capacity and found to have longest lasting effect of added K.The amount of K recovered at different incubation period increase with increase level of K added, and the added K recovered started declining at 30 days of incubation in all the soils. Clay and PH were identified as the agents of fixation. These had significant negative correlations with Fractional recovery. The calculated fertilizer factors required for these soils are basement complex (102mg/l), Basalt (96.5mg/l) and Sandstone 62.6mg/l and the values are against them. Following the decline in K recovery after 30 days on incubation, the best time to utilize added K should not be > 30 days.

Lighted liming may be done to increase pH and raise the release of K, from the relative low fertility status of these soils, other nutrients plus K, may be applied as required from the calculated fertilizer factor (Ff).

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