International Journal of Sustainable Agricultural Research
2018 Vol. 5, No. 1, pp. 10-18
ISSN(e): 2312-6477
ISSN(p): 2313-0393
DOI: 10.18488/journal.70.2018.51.10.18

ASSESSMENT OF POTASSIUM LEACHING BEHAVIOUR IN SELECTED SOILS OF SOUTHEASTERN NIGERIA

Umoh F. O[1]
Osodeke, V. E[2]
Akpan, U. S[3+]

[1]*Department of Soil Science, Akwa Ibom State University, Mkpat Enin, Nigeria*
Email: umohflorence@gmail.com
[2]*Department of Soil Science and Meteorology, Michael Opara University of Agriculture, Umudike, Umuahia, Nigeria*
[3]*Department of Soil Science and Land Resources Management University of Uyo, Akwa Ibom State, Nigeria*
Email: udyakpa2k2@yahoo.com

(+ Corresponding author)

Article History
Received: 8 January 2018
Revised: 16 April 2018
Accepted: 20 April 2018
Published: 23 April 2018

Keywords
Potassium
Leaching behaviour
Soils of Southeast Nigeria
Parent materials
Incubation time
Physical and hemical Properties soils
Leaching effect of K.

ABSTRACT

This study was conducted to asses Potassium leaching behavior of six (6) selected parent materials in Eastern Nigeria. The soils were formed from Shale, Coastal Plain Sand, Alluvium, Sandstone, Basement Complex and Basalt. A treatment solution containing O, 50, 100, 150 and 200mg/l of K prepared from KCl were added to 20g of soil samples in duplicated cups, the upper cup perforated, mixed thoroughly and allowed to dry. The cups were carefully covered and allowed to incubate for 1, 7, 30, 90 and 180 days, respectively. A total of 180 experimental units were generated and the treatment combinations were fitted into a Randomized Complete Block Design (RCBD), with 6 soil types representing the blocks for each of the incubation periods. The soil samples were kept moist with deionized water at weekly interval throughout the duration of incubation. At the set days, the concentrations of K in the leachate were measured using flame photometry. The K concentrations with days of incubation were plotted against rates of addition. The result shows that the leaching behavior of K in the parent materials varies under similar experimental conditions. Coastal Plain Sand, Sandstone and Basaltic Soil with high sand content exhibits highest amount of leaching compared to shale, alluvium and basement complex with high clay content. A higher K losses with high rates of K addition was observed and K decreased with time (days) of incubation.

Contribution/Originality: This study uses incubation methodology in assessing leaching potential of different soil types. This study is one of the very few studies which investigated leaching behaviour of soils of southeastern Nigeria. The paper's primary contribution is the finding that soils with high sand content exhibits high K leaching than others.

1. INTRODUCTION

Potassium is the third major nutrient element after Nitrogen and Phosphorous for crop production, required in large quantity for buildup of biomass. When Potassium is applied in the form of water soluble fertilizer, it can either be absorbed on the clay minerals, taken up by plants or leached out. The extent of each mechanism and component depends upon various factors including the nature of parent materials, soil physical and chemical properties, contact time, amount of K applied, rainfall or irrigation etc (Alfaro *et al.*, 2004; Kolahchi and Jalahi, 2007; Sharma and Sharma K, 2011). Leaching under field conditions has been regarded as the movement of nutrients from top soil down the profile beyond the root zone and potentially to surface water by lateral movement or lower to underground water (Broschat, 1995; Sharma, 1998). Fertilizers are applied at high rates to increase yield, yet little is known about the leaching potentials of nutrients from soils into the surrounding and underground water.

Barman *et al.* (2012) reported that soluble element K^+ are known to be quickly solubilized in the soil solution, with high quantity lost to leaching, which leads to poor plant growth and quality. Gikonyo *et al.* (2010) reported that the amount of nutrient leached increase with increasing rates of fertilizer applied and total nutrient concentration in leachate is higher than in soils. The greater P losses to the environment lead to an environmental pollution. Broschat (1995) observed that K^+ is associated with harmful algea blooms and eutrophication of lakes and ponds which decrease water quality. Meza *et al.* (2010) carried out a study to evaluate the effect of different column contact time on the release of inorganic constituents from bottom ash and demolition waste, it was observed that variations in contact time have no significant effect on the release of the selected constituents and leaching parameters at low liquid to solid ratios. Barman *et al.* (2012) reported that the rate of nutrient leaching decreased overtime and also controlled the release of fertilizers with time. Increasing costs of fertilizers, low yield of crops and concern with water quality have motivated interest to minimize losses due to leaching and to improve the efficiency use of fertilizers. Information on the leaching behavior of potassium in Eastern Nigeria is scanty. The study is therefore aim at evaluating the level of K leaching losses in these soils using column leaching experiments.

2. MATERIALS AND METHODS

2.1. Description of the Study Area and Soil Sampling

Six surface soil samples were used for the study to represent the six (6) dominant soil parent materials in Eastern Nigeria. These include; Odukpani located on latitude 5^0 7^1 N and longitude 8^0 20^1 E, derived from shale formation with a smectite clay mineralogy and typic hapludult (USDA) soil type, Umudike (Latitude 4^0 59 N and longitude 7^0 49^1E derived from coastal plain sand with kaolinitic clay mineralogy and typic paleudult (USDA) soil classification, Itu lies at coordinate of 5^0 10^0 N and 7^0 59^1 E form from alluvium deposit, classify as Rhodic tropudults with Kaolintic clay mineralogy Amaeke derived from sand stone, (coordinate 5^0 33^1N 7^0 3E with smedite clay mineralogy classify as typic Tropaquents, Akamkpa with coordinate 5^0 19^1 N 8^0 20^1E form from Basement complex, with smectite clay, as Typic Tropaquent USDA classification) Ikom (coordinates of 5^0 57^1 N8^0 42^1 E) form from Basalt dominated by smectile clay with Typic Dystropept (USDA) classification.

The climate is humid tropical with annual rainfall of about 2163 – 3000mm with 1-3 dry months in the year. Mean annual temperature varies between 27 – 28^{0}C with relative humidity of 75 – 80% (Okorie, 1987). The figure 1 shows the map of the study location.

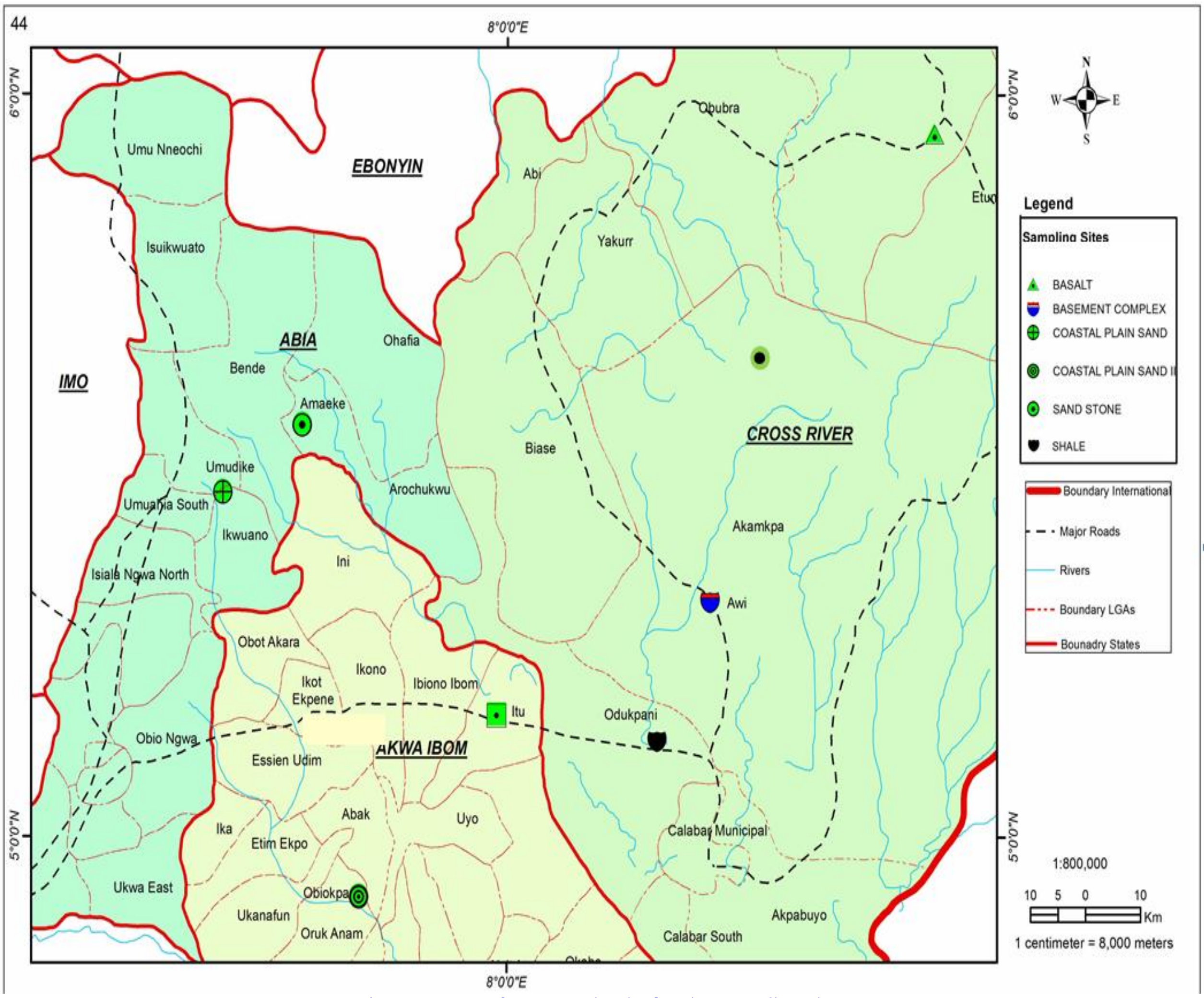

Figure-1. Map of Eastern Nigeria showing Sampling Sites

Source: GIS Laboratory, Office of the Akwa State Surveyor General

2.2. Incubation Procedure and Laboratory Analysis

Twenty grams of soil was weighed into a duplicated cup with a capacity of 23cm in dimeter abd 13cm in length and the upper cups perforated (Ayodele and Agboola, 1981). A 20ml portion of the treatment solution containing 0, 50, 100, 150 and 200mg/l prepared from KCl was added to each of the soil in the cups, mixed thoroughly for effective mixing of the K solution with the soils and allowed to dry. The cups were carefully covered and allowed to stand for 1, 7, 30, 90, 180 days respectively. The treatment combinations were then subjected into a Randomized Complete Block Design (RCBD), with 6 replications or blocks. The soils were kept moist with 30ml distilled water at weekly intervals and covered for the duration of incubation. At the set days, the potassium in the leachate was determined using flame photometry.

Parts of the soil samples were air dried, crushed and sieved through 2mm size sieve and used for the following analysis: Particle size distribution was analysed using hydrometer method (Klute, 1996) soil PH was determined in water 1:2.5 soil and water ratio in KCl using glass electrode as described by Udo *et al.* (2009). Organic matter was determined by wet-oxidation method described by Udo *et al.* (2009). Available phosphorous was determined by Udo *et al.* (2009) after extraction by Bray P-I extractant. Exchangeable cations were extracted with neutral NH_4OA_C. Calcium and Magnesium were determined in the extract by EDTA titration as described by Udo *et al.* (2009). Potassium and Sodium was determined by the use of flame photometer. Effective cation exchange capacity (ECEC) was obtained by the summation of the exchangeable cations and exchangeable acidity as described by Udo *et al.* (2009).

3. RESULTS AND DISCUSSION

The physical and chemical properties of selected soils of the study area are shown in Table 1. The particle size analysis showed that the soils were generally light textured and the variation in the texture reflects the differences in the parent materials. This difference in texture will affect water and nutrient leaching and retention as well as suitability of soils as a rooting medium in these soils (Aguilera *et al.*, 2012). The soil pH in water and KCl ranged from 5.0 – 6.1 and 4.4 – 5.9, respectively with a mean of 5.4. These range are generally, considered slightly acidic condition which is considered satisfactory for crop production in this zone. All the pH values in salt extract were less than those in the aqueous extract, indicating that the soils were negatively charged at their natural state (Villapando and Graetz, 2001). The soils were non-saline with low electrical conductivity values (Table 1), indicating that the soils are salt free. Organic matter contents of the soils were above the critical level of (2gkg^{-1}) proposed by Aduayi *et al.* (2002) for soils of Eastern Nigeria. Total N were below the critical level (2gkg^{-1}) and P level lower than the critical level of 12-15mgkg^{-1} except sandstone soils (Aduayi *et al.*, 2002). The order of abundance of exchangeable base for the soils was Ca>Mg>K>Na. The effective cation exchange capacity (ECEC) was low except in Basaltic soil with critical level of 12 cmolkg^{-1}. The low ECEC values are indication of the presence of low activity clays. The base saturation values were high in the soils, except in soil derived from Basement Complex with moderate level of 47.1cmolkg^{-1} (Enwezor *et al.*, 1989). This result agreed with the findings of Halrvin and Beaton (2006) which stated that the release of nutrients by soils is influenced by the cations.

Table-1. Physico- chemical properties of the soils

Soil properties		Sandstone (Amaeke)	Coastal plain sand (Umudike)	Alluvium (Itu)	Shale (Odukpani)	Basement Complex (Akamkpa)	Basalt (Ikom)
Sand	%	74.2	78.2	64.8	46.4	69.0	69.2
Silt	%	14.4	6.6	12.0	10.2	10.6	16.2
Clay	%	11.4	15.2	23.2	43.4	20.4	14.6
Texture		SL	SL	SCL	SC	SCL	SL
pH(H_2O)		5.6	5.0	6.1	5.8	5.4	5.6
pH (Kcl)		5.1	4.7	5.9	5.4	5.1	5.4
EC (ds/m)		0.1	0.1	0.3	0.2	0.06	0.1
O M	gkg^{-1}	4.8	3.2	4.2	3.4	2.7	5.0
Total N.	gkg^{-1}	0.2	0.3	0.2	0.2	0.2	0.2
Ava. P	gkg^{-1}	20.0	5.0	7.5	5.7	3.0	7.3
Ex. Ca	cmolkg^{-1}	6.0	4.1	3.8	4.7	3.0	5.8
Mg	cmolkg^{-1}	2.6	2.3	1.5	3.0	1.2	3.4
Na	cmolkg^{-1}	0.05	0.04	0.08	0.08	0.04	0.05
K	cmolkg^{-1}	0.1	0.08	0.2	0.3	0.1	2.2
EA	cmolkg^{-1}	2.1	3.2	3.0	1.25	4.5	2.3
ECEC	cmolkg^{-1}	11.07	9.7	8.6	9.3	9.0	13.7
Base Saturation %		79.8	67.1	65.2	86.6	49.1	83.3

EC – Electrical Conductivity, OM – Organic Matter, AV.P- Available Phosphorous, EA-Exchangeable Acidity, ECEC – Effective cation Exchange Capacity, SL – Sandy Loam, SCL – Sandy Clay Loam, SC – Sandy Clay

3.1. The Leaching Behavior of Potassium (K) in Soils

The leaching rate of applied K in the soils of the study area was obtained from the relationship between K extracted from the leachate at different rate of applied K and at different incubation periods and are presented in Figures below, the letters A to E denote the (contact time) days of incubation as A – 1, B – 7, C – 30, D – 90 and E – 180 days. The graphs are plots of the concentration of K in leachate and amount or rates of K added.

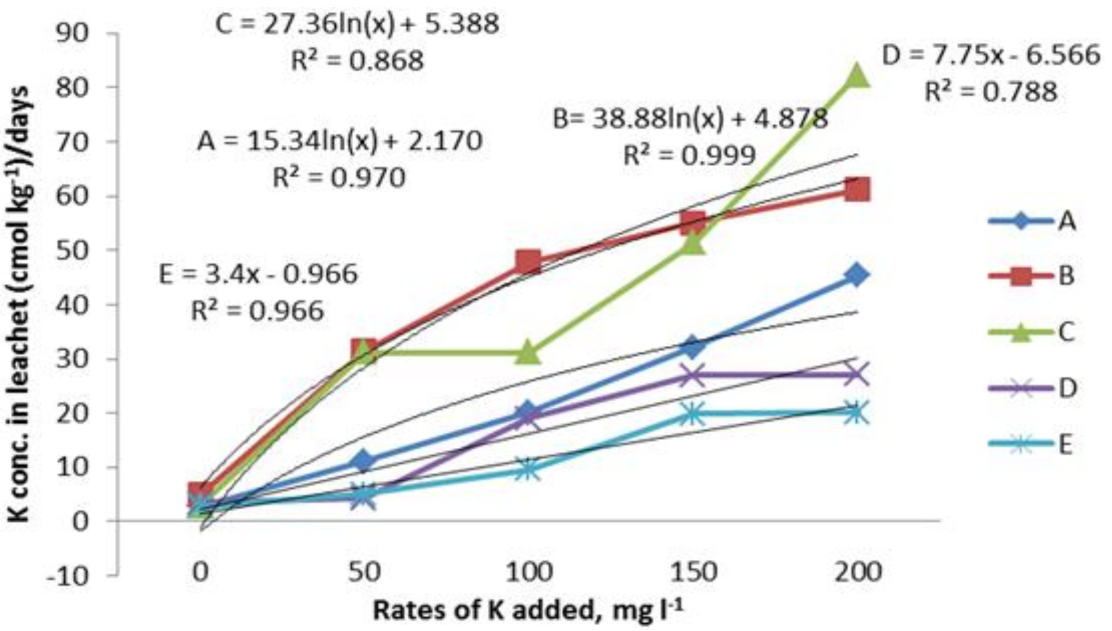

Figure-2. Plot of K concentration in leachate VS rates of K added (cmolkg^{-1}) in shale parent material (Odukpani)
Source: Authors Work (2015)

It was observed from Figure 1 in shale soils that the rate of leaching increase with increasing rates of K added. The concentration of K in the leachate were higher at (c) 30 days and decrease at 90 days (D) indicating long period of leaching effect of added K in shale soil. The effect could be attributed to high clay content in that soil (Table I) in which that high proportions of the solution K were adsorbed on the external surfaces and edge of charge sites of clay. Kolahchi and Jalahi (2007) observed that those with high charge density retain more K than those with low charge density on the layer silicate. The relationship between the concentration in leachate and amount of K added is strongly affirmed with R^2 values in the figure, ranging from 79 to 96%.

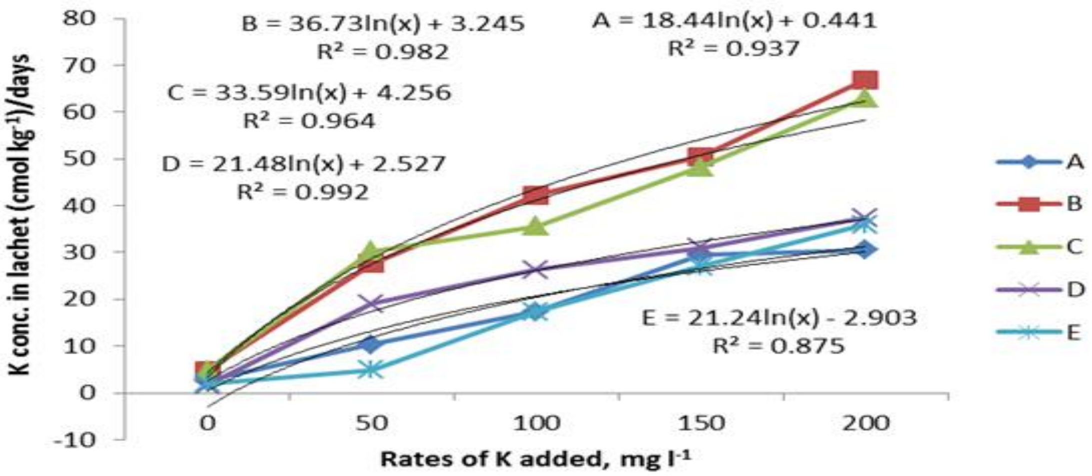

Figure-3. Plot of k concentration in leachate VS rates of K added (cmolkg^{-1}) in Coastal Plain Sand (Umudike).
Source: Authors Work (2015)

In coastal plain sand soils (Figure 3) there was a gradual increase in the K leaching with rates of K added. The highest K losses was observed at 7th days of contact time termed (B) and decreases at 30 days (c), indicating that K in Coastal Plain Sand has short period of leaching effect of added K. This could be attributed to the Sandy nature of the parent material (Table 1). This showed that light texture soils are more prone to high leaching losses. The results are in agreement with those obtained by Sharma and Sharma K (2011) who reported higher leaching of Potassium in sandy loam soil.

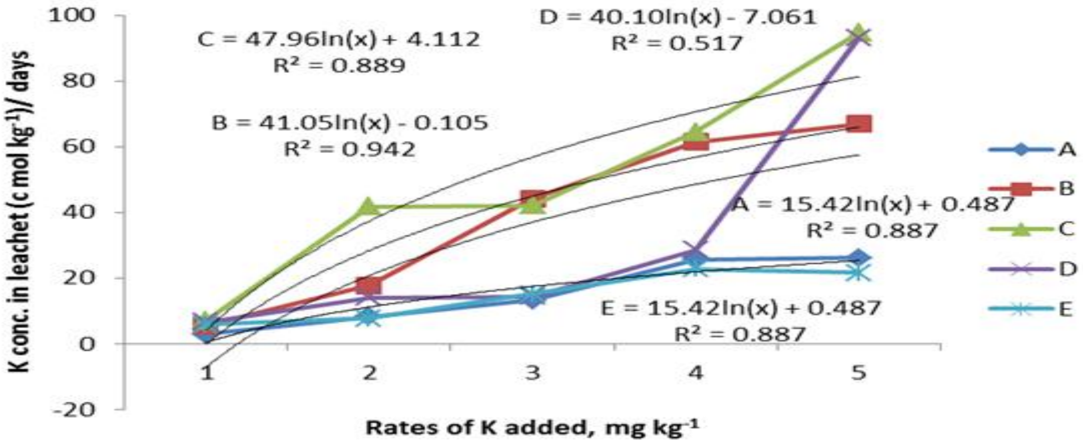

Figure-4. The plot of K concentration in leachate VS rates of K added cmolkg^{-1} in alluvium soil (Itu)
Source: Authors Work (2015)

In sandstone soils (Figure 4), the concentration of K in leachate increases with increasing rate of K added in sandstone soil. The highest K in the leachate was observed at 90 days (D), indicating long period of leaching effect of added K. This result may be due to higher amount of clay in that soil as shown on Table 1. Kolahchi and Jalahi (2007) reported that soil rich in clay have higher capacity to retain potassium ion.

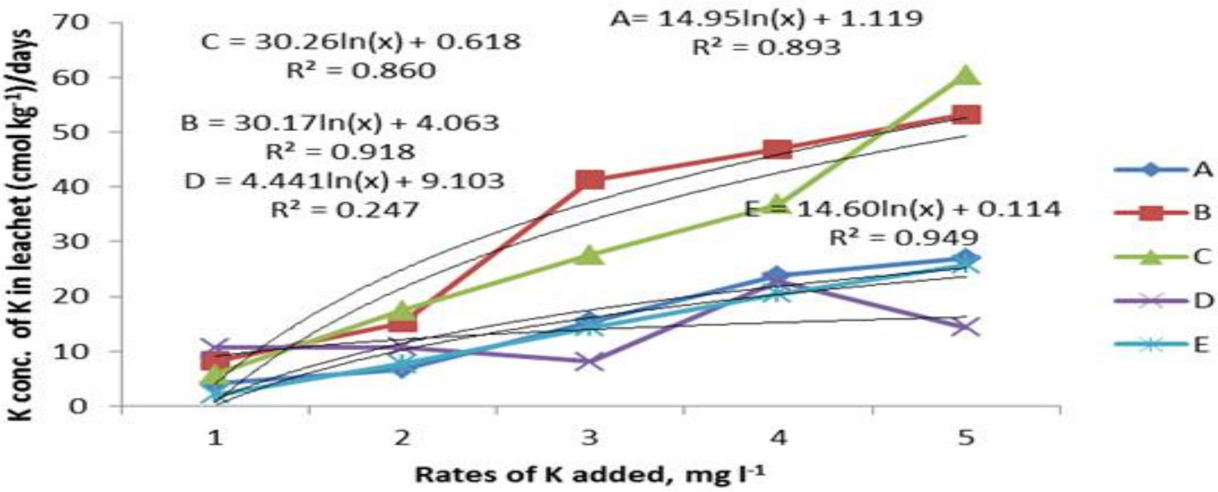

Figure-4. Plot of K concentration in leachate VS rates of K added (cmolkg^{-1}) in sandstone parent materials (Amake).
Source: Authors Work (2015)

In basement complex soils (Figure 5) a gradual increase in K losses with increase rates of K added in the soil. The variation in days of incubation indicated an irregular pattern with Lesser concentration. The highest K losses was observed at the 7th days indicating short lasting effect of added K, then decrease with others days. These finding could be attributed to the high sand content in that soil (Table 1). Sandy Soils has weak interaction of K^+ in the soil solution (Kolahchi and Jalahi, 2007) which is eventually leached down.

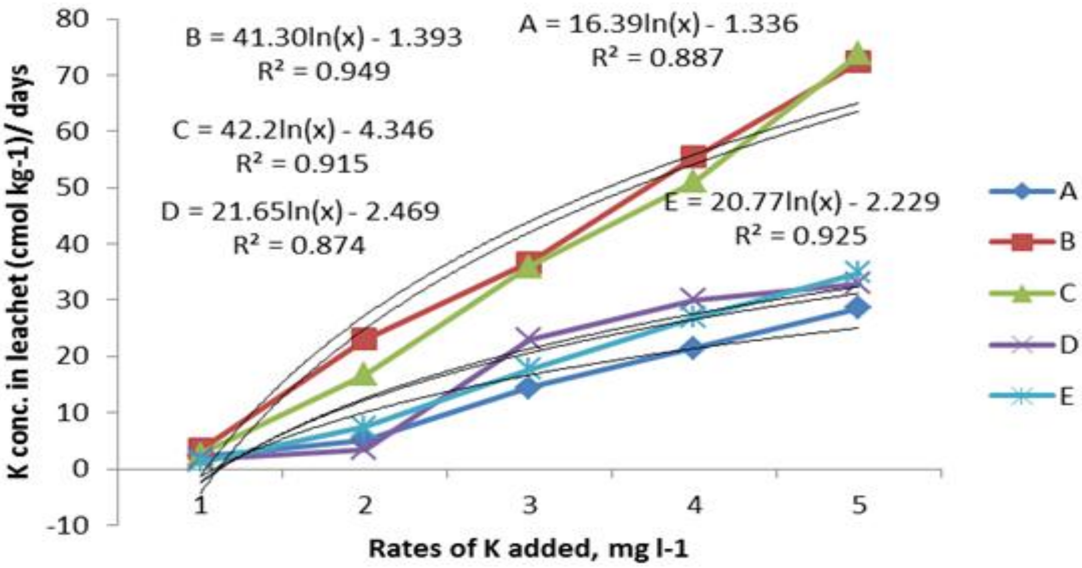

Figure-6. Plot of K concentration in leachate in days VS rates of K added (cmolkg^{-1}) in Basement complex (Akamkpa)
Source: Authors Work (2015)

From figure 6, the highest concentration of K^+ was observed at (c) 30 days and decrease at 90 days. The longativity of added K in that soil could be associated with high amount of clay (Table 1) in which K was held. The concentration of K in leachate increased with the rates of K added as fitted in the model. Sharma (1998) reported that soil texture has a great effect on leaching of potassium.

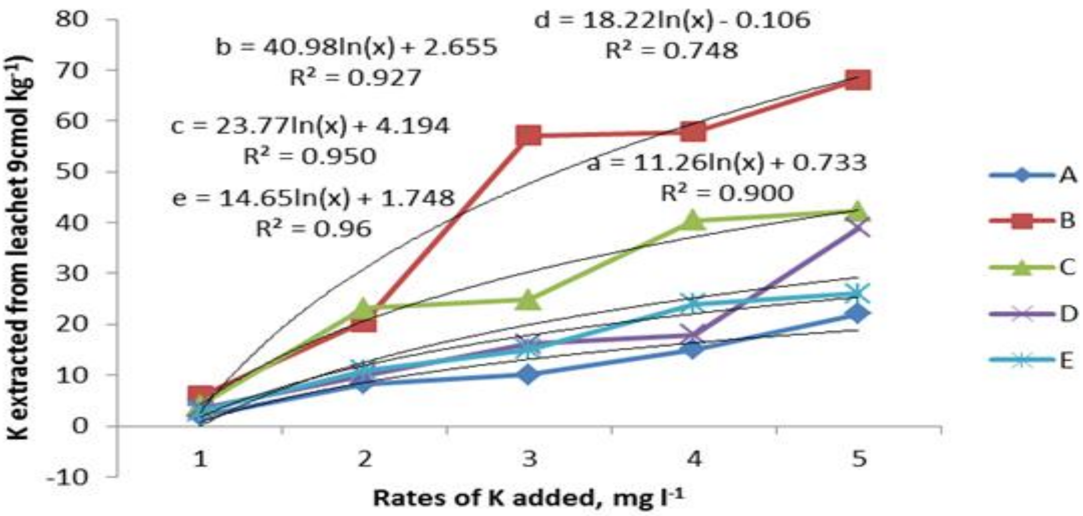

Figure-7. Plot K concentration in leachate in days VS rates of K added (cmolkg^{-1}) in Basaltic Soils (Ikom).
Source: Authors Work (2015)

From figure 7, the highest K release in leachate was observed at 7th days termed (B) indicating short lasting effect of added K. The release of K in basaltic soil could be attributed to high organic matter content in basaltic soil (Table 1) which form complexes with the soil matrix and ease the released of K into the soil solution (Agebede, 2009) which could be leached out or taken up by plant. The concentration of K^+ in leachate increased with rates of addition and the relationship is strongly affirmed with the R^2 values in the figure. Generally, the leaching of K in these soils decreases with days of incubation.

4. CONCLUSION

Physico-chemical properties of soils shows that, soils were moderately acidic, light textual, salt free and most of the soils were low in nutrients. The concentration of K in leachate at different incubation period increase with increasing level of K added and decrease with time (days) of incubation. The soils of shale, alluvium and basement complex had long lasting effect of added K and found to have low leaching potential, while soil form from coastal plain sand, sandstone and basaltic had short lasting effect of added K and higher leaching potential. Therefore, for effective application and utilization of K^+, split application is recommended for these soils.

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
Contributors/Acknowledgement: All authors contributed equally to the conception and design of the study.

REFERENCES

Aduayi, E.A., V.O. Chude, B.A. Adebusuyi and Olayiwola, 2002. Fertilize use and management practices for crops in Nigeria. 3rd Edn., Abuja, Nigeria: Produced by Federal Fertilizer Department, Federal Ministry of Agriculture and Rural Development. pp: 23-73.

Agebede, O.O., 2009. Understanding of soil and plant nutrition. Nassarawa State: Salman Press. pp: 183 – 217.

Aguilera, P.P., M. Motavali, A. Gonzales and C. Valdivia, 2012. Initial and residual effects of organic and inorganic amendments on soil properties in a potato based cropping system in the Bolivian Andean highlands. American Journal of Experimental Agriculture, 2(4): 641 – 666. *View at Google Scholar | View at Publisher*

Alfaro, M.A., S.C. Jarvis and P.J. Gregoty, 2004. Factors affecting potassium leaching in different soils. Soil use and Management, 20(2): 182 – 189. *View at Google Scholar | View at Publisher*

Ayodele, O. and A.A. Agboola, 1981. Evaluation of phosphorous fixation capacity of tropical savanna soils of Southeastern Nigeria. Soil Science Society of America Journal, 45(3): 462 – 464. *View at Google Scholar*

Barman, P.J., S.A. Kartha, S. Gupta and B. Pradhen, 2012. A study on leaching behavior of Na, Ca and K using column leach test. World Academy of Science, Engineering and Technology, 6(10): 679-683. *View at Google Scholar*

Broschat, T.K., 1995. Nitrate, phosphate, and potassium leaching from container grown plants fertilized by several methods. Horticultural Science Journal, 30(1): 74-77. *View at Google Scholar*

Enwezor, W.O., J.E. Udo, N.J. Usoro, K.A. Ayotade, V.O. Chude and C.I. Udegbe, 1989. Fertilizer use and management practices for crops in Nigeria. Series 2. Lagos: Federal Ministry of Agriculture, Water Resources and Rural Development, 18.

Gikonyo, E., A.R. Zaharah, M.M. Hanafi and R. Anuar, 2010. Phosphorous leaching in an acid tropical soil. Recapitalized with phosphate rock and triple superphosphate. Scientific World Journals, 10: 1498 – 1508. *View at Google Scholar | View at Publisher*

Halrvin, I.I. and J.D. Beaton, 2006. Soil fertilizer: An introduction to nutrient management, prentice. 7th Edn., New Delhi: Hall of India. pp: 199-218.

Klute, A., 1996. Methods of soil analysis: Part 1. Physical and minieralogical properties. 2nd Edn., U. S. A: CSSA, SSSA Madison, W. I.

Kolahchi, Z. and M. Jalahi, 2007. Effect of water quality on the leaching of potassium from sandy soil. Journal of Arid Environment, 68(4): 624-639. *View at Google Scholar | View at Publisher*

Meza, S.L., U. Kalbe, W. Berger and F.G. Simon, 2010. Effect of contact time on release of contaminants from granular waste materials during column leaching experiment. Waster Management, 30(4): 565 – 571. *View at Google Scholar | View at Publisher*

Okorie, P.E., 1987. Effect of Age and seasonability on cropping and cropping development of Gemlinearborea Roxb. In a pulpwood plantation. Unpublished Ph.D Thesis, University of Ibadan.

Sharma, U.C., 1998. Influence of soil texture and rainfall on leaching of potassium and its recovery by potato (Solonum tuberosum). Indian Journal of Agricultural Science, 59(11): 713-717. *View at Google Scholar*

Sharma, V. and N. Sharma K, 2011. Potassium leaching from two texturally variable in potato growing alluvial soils of North – Western India. Journal of the Indian Society of Soil Science, 59(4): 343-348. *View at Google Scholar*

Udo, E.F., O.T. Ibia, J.A. Ogunwale, A.O. Ano and I.V. Esu, 2009. Manual of soil, plant and water analysis. Lagos: Sibon Books Ltd.

Villapando, R.R. and D.A. Graetz, 2001. Phosphorous sorption and desorption properties of the spodic harizon from selected Florida spodo Soils. Soils Science Society of America Journal, 65(2): 331 – 339. *View at Google Scholar* | *View at Publisher*