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ASSESSMENT OF EXTRACTANTS FOR SOIL AVAILABLE POTASSIUM DETERMINATION IN THE SELECTED SOILS OF KWARA STATE, NIGERIA

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Abstract

Response of potassium (K) correlated with extracted K using five laboratory methods: neutral N NH₄OAc pH 7.0; NH₄OAc pH 4.8, 0.01M CaCl₂, 1N Hot HNO₃ and 0.5N NaHCO₃ pH 7.0 by sorghum were determined in four selected soils from twenty locations in Kwara State, Nigeria in the green house to ascertain the ideal procedure for routine analysis. Regression equations were derived for each soil between K uptake by sorghum and level of K applied and, by extrapolation, the A-value, which represented the amount of soil K available as applied K, was determined. The data from the five laboratory methods were correlated with A-value, the zero-level K uptake, and with one another. The results showed that 0.01M CaCl₂ only, extracted more K than the A-value, which was greater than the K extracted by the other methods. The data of all methods were, however, significantly correlated ($p < 0.05$) with A-value while zero-level K uptake had a highly significant correlation with data of 0.01M CaCl₂ (0.99) and low values with that of the other methods. The neutral normal NH₄OAc pH 7.0 correlated relatively high and positively with N NH₄OAc pH 4.8, 0.01M CaCl₂, and 0.5N NaHCO₃ pH 7.0, but negatively (-0.60) with 1N Hot HNO₃. However, the neutral N NH₄OAc pH 7.0; NH₄OAc pH 4.8 correlated relatively higher and positively with one another (0.93) although they both extracted unequal amounts of K. Thus, both could be conveniently handled in the routine work in place of hot 1 N HNO₃ for the evaluation of K availability indices for sorghum in the region.

Keywords: A-value, available K, extractants, sorghum

INTRODUCTION

Potassium (K) availability designates complex circumstances, and it is a property that is contingent on soil factors and plant physiology (Grimme, 1985). Although, the bulk of total soil K is in the mineral fraction (Harpreet, 2019; Sparks & Huang, 1985). The kinetics of non-exchangeable K (non-exch-K) released from soils have been confined to the differences in K release kinetics due to either mineralogical make-up of the soils or the size of soil aggregate fractions (Cox & Joern, 1997; Martin & Sparks 1983; Dhillon *et al.*, 1989, Srinivasarao *et al.*, 2006). While, exchangeable K (exch-K), or available K, is held by negatively charged clay minerals and organic matter in

soils, non-exch-K consists predominantly of interlayer K of non-expanded clay minerals such as illite and lattice K in K minerals like K feldspars. The best technique for determining K releasing power for use as a soil test in a fertilizer forecast model gives the minutest interception and a slope about unity once fitted to K uptake of the plants as plotted on the Y-axis of a suitable graph. This would signify that the quantity extracted by that method is almost equivalent to crop removal (Garman, 1957). Thus, no single method meets this criterion. The next best technique to evaluate the credibility of a chemical procedure is based on the correlation coefficient (r) or percent predictions (r^2) between K release and K supply. The method which best explains the maximum variation in

the K supply power of the soil would be the best to predict the plant-available K (Kirkman *et al.*, 1994).

A variety of extracting solutions are used to assess the plant-available K in different parts of the world (Knudsen *et al.*, 1982). All chemical methods measure more or less similar amounts of the immediately available K, but vary in their ability to predict the K available to plants from the non-exchangeable K fractions, since the K available from the non-exchangeable pool depends on soil factors and the plant species (Lee & Metson, 1977; Memon *et al.*, 1988). The conventional 1M NH₄OAc exchangeable K contributes significantly to crop nutrition (Cox *et al.*, 1999). However, boiling HNO₃ method can extract some non-exchangeable K as well as exchangeable and soluble K (Knudsen *et al.*, 1982). Consequently, the objective of this study was to compare some of the many extractants for estimating available K and suggest the method(s) best adaptable for sorghum and routine laboratory soil analysis in southern Guinea Savanna of Nigeria.

MATERIALS AND METHODS

Greenhouse study

The soils used were collected from four Local Government Areas (LGA) of the Kwara State with different parent materials and cropping histories. The locations are: Tsaragi in Edu LGA, Maletete in Mooro LGA, Otteh in Asa LGA and Omu-Aran in Irepodun LGA of the state. The soils were formed on the basement complex rocks except Tsaragi's which formed on sandstone. The surface soils (0-15cm) were collected using random sampling technique from twenty locations within each LGAs and bulked to give a composite sample before transporting to the laboratory. The composite samples were air-dried, ground and sieved to pass through 2mm sieve. The sub-samples of the soils were analyzed for physico-chemical properties using standard laboratory procedures prior to pot experiment.

Soil samples weighing 0.75kg each were placed in 1000 ml-capacity plastic bowls. Nutrient solutions containing 0.177g (NH₄)₂PO₄ were applied to the soil in each bowl at the rate of 100 and 110 kg ha⁻¹ of nitrogen (N) and phosphorus (P), respectively. Potassium chloride salt was used to apply the levels of K equivalent to 0, 15, 30, 45 and 60 kg ha⁻¹. The K fertilizers were applied a week after germination in three (3) replicates. The content of each bowl was watered to approximately field capacity daily. Five *Sorghum bicolor* seeds were sown in each bowl which was thinned to two plants per bowl at one week. The thinned plants were left inside each bowl. Harvesting of the sorghum tops were carried out after four week, dried in the oven at 60°C for 3 days, weighed and milled into a fine powder. The ground plant tissues were wet digested with a mixture of HNO₃ and HClO₃ (Issac & Kerber, 1971) and K in digests determined by flame photometry.

Laboratory methods

Method I: A-value (Fried & Dean, 1952; Ekpete, 1972b)

The regression equation between total K uptake by sorghum tissue and the amounts of K applied was derived for each soil using simple regression analysis. By extrapolation, the negative value of applied K at zero K uptake was determined. This value with the sign changed to positive was regarded as the A-value, that is, the soil K that was available as K in the applied fertilizer.

Method II: potassium uptake at zero level

This was obtained from the analysis of results and represented the amount of K taken up by the plants from the soil that had received no K fertilizer (Absolute control).

Extractants used

Method III: potassium uptake as measured by N NH₄OAc pH 7.0 for 60minutes

Method IV: potassium uptake as measured by N NH₄OAc pH 4.8 for 60minutes

Method V: potassium uptake as measured by 0.01M CaCl₂ (Woodruff and Mcintosh, 1960)

Five grams of soil was extracted with 50ml 0.01M CaCl₂ for 1 hour. The sample was filtered through Whatman No. 42 filter paper. The extract was made up to mark with 0.01M CaCl₂.

Method VI: Potassium uptake measured by hot N HNO₃ (Pratt, 1951) modified by Ekpete (1972a). Five grams of soil was extracted with 50ml hot N HNO₃ by standing for 15 minutes, boiling for 10 minutes and neutralized with NH₄OH. After which, the precipitate of Al and Fe were filtered.

Method VII: Potassium uptake measured by Olsen's solution (0.5N NaHCO₃, pH 7.0).

Five grams of soil was extracted with 50ml 0.5N NaHCO₃ pH 7.0 for 15 minutes.

In all cases, K in the final filtrate was determined by a flame photometry. The amounts of K, extracted in triplicate by each method, were calculated and the probable

relationship determined by a spearman correlation and regression analysis. The correlation coefficients, regression equations, and where necessary, regression lines were obtained for the data of the different methods.

RESULTS AND DISCUSSION

Some properties of the soils employed in the study are presented in Table 1. The soils were generally loose ranging between loamy sand to sandy loam in texture. The organic matter content was low, this is partly attributed to annual burning; a phenomenon which reduces the build-up of organic matter. The soils were generally slightly acidic ranging between 5.70 and 6.30 except the Omu-Aran soil which was strongly acidic (4.00). The effective cation exchange capacity was generally low with exchangeable calcium being the dominant cation on the exchange site except for the Tsaragi's soil formed on sandstone that had magnesium dominating the exchange site.

Table 1: Selected physico-chemical properties of the soils used in the study.

Soil Variables	Locations			
	Otteh	Omu-Aran	Tsaragi	Maletе
pH (1:1, H ₂ O)	6.30	4.00	6.30	5.70
Organic carbon (g kg ⁻¹)	13.60	16.80	20.30	3.60
Gravel content (g kg ⁻¹)	110.60	144.50	18.10	13.80
Clay (g kg ⁻¹)	63.20	144.80	63.20	63.20
Silt (g kg ⁻¹)	152.80	200.00	152.80	152.80
Sand (g kg ⁻¹)	784.00	655.20	784.00	784.00
Textural Class	Loamy sand	Sandy loam	Loamy sand	Loamy sand
Bilk density (kg m ⁻³)	1520	1570	1520	1520
Porosity (%)	42	40	42	42
Hydraulic conductivity (mm hr ⁻¹)	108.7	52.4	108.7	108.7
Total Acidity (cmol kg ⁻¹)	0.28	0.60	0.24	0.20
Exchangeable bases (cmol kg ⁻¹)				
Calcium	4.00	2.00	2.40	4.00
Magnesium	2.00	2.40	5.20	3.20
Potassium	0.47	0.14	0.07	0.01
Sodium	0.13	0.13	0.10	0.07
*ECEC	6.88	5.27	8.01	8.48

N. B: *Effective Cation Exchange Capacity = TEB + Total Acidity; TEB = \sum (Exchangeable bases)

Table 2: Mean extractable K and correlation coefficients between the various methods of soil available K determination

Method	I A-value	II Zero uptake	III N NH ₄ OAc pH 7.0	IV N NH ₄ OAc pH 4.8	V 0.01M CaCl ₂	VI Hot N HNO ₃	VII 0.5N NaHCO ₃ pH 7.0
I	-						
II	0.57	-					
III	0.98*	0.39	-				
IV	0.73	0.44	0.93	-			
V	0.94*	0.99*	-0.60	-0.71	-		
VI	0.92*	0.28	0.99*	0.95*	-0.54	-	
VII	0.70	0.33	0.88	0.81	-0.84	0.80	-
Mean Extractable K	18.92	14.96	0.17	0.15	0.29	0.18	0.13

*correlation is significant at 0.05 level (2 tailed)

The mean amount of K extracted by the various methods with respective correlation data are presented in Table 2.

Relationship between A-value and other extraction methods

For plants grown at a zero level K application, 0.01M CaCl₂ (method V) extracted more K from the soils than the A-value which was greater than the K extracted with each of the other methods ($r = 0.99$). Methods III to VII had extractable K that correlated significantly with the A-value.

The highest correlation coefficient was obtained between A-value and N NH₄OAc pH 7.0 ($r = 0.98$) followed by methods V and VI ($r = 0.94$ and 0.92 , respectively). Although, methods IV and VII recorded relatively high correlation coefficients of 0.73 and 0.70 , respectively, both were below the magnitude of 0.90 chosen as the minimum to qualify any method for test of precision.

Relationship between extraction methods

The trends of the magnitudes of the correlation coefficients of the different methods with A-value and zero level K uptake differ with the mean of methods II & III to VII ($r = 0.48$) less than I & III to VII, $r = 0.85$. The data of methods III and V had a negative r value (-0.60)

which implied that the K extracted by method V decreases as that extracted by method III increases, insinuating different concentrations of K extracted by both methods. Method V was also negatively correlated with other methods although statistically at par in all cases. The result of method VI had relatively high r value with methods III, IV and VII. Whereas almost equal values of K were extracted with methods III and VI (Sobulo, 1969 and 1973), much less K was extracted with methods IV and VII. The result of methods III and IV correlated well with each other and with exchangeable K of method VI. The result of method VII had a high correlation with methods III, IV and VI, but negatively high correlation coefficient which was not significant at 5% level.

It has been generally accepted that soil K existed in various forms in equilibrium. The more available forms of soil K were depleted; they were replenished with difficulty available forms, which was in turn made good from the non-available forms. Thus, the success of any chemical method for evaluating K release depends on its ability to predict the immediately available K (solution K and exchangeable K), and its ability to predict the rate of replenishment from the non-exchangeable K forms. This explains why the K taken up by the plants from a soil that received no fertilizer K (Table 2) was in the same range with the A-

value. This evidence was also affirmed by the mean exchangeable K (14.96 kg ha^{-1}) at the end of the experiment for a zero level application.

The NH_4OAc pH 7.0 and 4.8 extracted more K than the A-value which implied that a substantial concentration of K was in the available form. Although, both NH_4OAc pH 4.8 and hot N HNO_3 methods recorded relatively high correlation coefficients with NH_4OAc pH 7.0, only the latter was significant at 5% significant level. Hot N HNO_3 furnished heat to the extraction reaction and this resulted in the release of difficultly available and perhaps some non-available K from the soil. It gave the highest correlation coefficient with N NH_4OAc pH 7.0. This implied that a better part of the extractable K in the soils studied were in the difficultly available and non-available forms.

The high relationship between hot N HNO_3 and the A-value indicated that the fraction of K released to available forms resulted from the shift in the soil K equilibrium. This shift in equilibrium occurs as the initially available K absorbed by the roots becomes constant and proportional to the A-value (Hunter & Pratt, 1957). Consequently, the more easily released the difficultly and non-available K fractions was a function of the originally available K in these soils (Ekpete, 1972b; Kirkman *et al.*, 1994).

Among the five laboratory methods employed in the assessment of available K status in these soils, NH_4OAc pH 7.0 and hot N HNO_3 would be suitable for predicting the magnitude of the response with K application, while hot N HNO_3 and 0.01M CaCl_2 would be ideal for with or without K application, evident from the relatively high correlation coefficients with percent uptake of K (Table 3).

Since, the mean correlation coefficient between the results of the five laboratory methods and the A-value was relatively higher than that of between them and zero-level uptake, the former would be a better index for the availability of K in preference to the latter. This submission is tenable because the A-value

represented soil K that is as available as applied K and zero-level uptake was a component of the data used in computing it (Epkete, 1972b). The difference between the data of the methods employed as well as the negative association between the NH_4OAc pH extraction methods and 0.01M CaCl_2 would be attributed to the difference in species of the extractant and the concentration of the K-displacing cations between these methods. While the difference between the two NH_4OAc methods was the proportion of the acetate to ammonia solution which was not justified since they did not extract equal amounts of K, although, their data had a very high correlation. However, both could be conveniently handled in routine work in place of hot N HNO_3 .

Table 3. Relationship between extractants and percent uptake of potassium of sorghum tops

Extractants	Correlation coefficient (r)
NH_4OAc pH 7.0	0.34
NH_4OAc pH 4.8	0.37
N HNO_3	0.80
0.01M CaCl_2	0.83
0.5N NaHCO_3 pH 7.0	0.36

CONCLUSION

It was more accurate to use the A-value determined by the extrapolation of the regression of K uptake upon the level of K applied to potted plants than to use only the uptake of K at a zero-level application as the index for soil K availability. For the southern Guinea Savanna soils of Nigeria studied, the data for all methods employed in the testing for soil K availability correlated positively with the A-value. Although, none of the laboratory K data was equal to the A-value. NH_4OAc pH 7.0 extracted more K than the A-value, which was greater than the K extracted with the other methods. The highest correlation coefficient was found between A-value and K extracted in the laboratory with NH_4OAc pH 7.0 ($r = 0.98$), 0.01M CaCl_2 ($r = 0.94$) and hot N HNO_3 ($r = 0.92$). These three alternative methods were thus

considered most suitable for the routine evaluation of K availability indices in the southern Guinea Savanna of Nigeria. However, hot N HNO₃ and NH₄OAc pH 7.0 could be employed in the soil studies with K application, while 0.01M CaCl₂ and NH₄OAc pH 7.0 are ideal, irrespective of K application or not.

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