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Comparison of Selected Extractants for the Estimation of Available K in Soils of Edo State of Central Southern Nigeria

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ABSTRACT

Comparison of five selected extractants for estimation of available K in soils of Edo State of Central Southern Nigeria was carried out in a greenhouse with maize as the test crop. The five extractants used were distilled water, 0.5 N $NaHCO_3$ (pH 8.5), 0.01 M $CaCl_2$, 0.1 N HNO_3 and 1 N NH_4OAc (pH 7). Nine composite surface (0 – 15 cm depth) and subsurface (15– 30 cm depth) soil samples were used in this study. The amount of extractable K by 1 N NH_4OAc (pH 7) and 0.1 N HNO_3 showed the highest significant linear correlation with K uptake and dry matter yield with 'r' values of 0.910*, 0.895*** and 0.718***, 0.754*** (P = 0.001) respectively, when compared with distilled water, 0.5 N $NaHCO_3$ (pH 8.5) and 0.01 M $CaCl_2$. The use of 1 N NH_4OAc (pH 7) and 0.1N HNO_3 soil tests could be recommended because they appeared to have almost equal efficiency in terms of the ability of extracting available K from these soils.**

Keywords**:** available K, Central Southern Nigeria, Edo State soils, extractants

The economy of Edo State of Central Southern Nigeria is largely agro-based and about 70% of the teeming population are engaged in subsistence agriculture. Mixed cropping is the cropping pattern adopted by the peasant farmers in this region. The crops that are mostly grown are yam, maize, melon, cassava, pineapple, pepper, etc., but maize appears to be the most dominant crops.

In Nigeria, extractants such as ammonium acetate (NH_4OAc), HCl, HCl+ H_2SO_4 (Mehlich 1), $NaHCO_3$, are used for the determination of available K in soils as in Europe and America but the adoption for Nigeria is not based on extensive research (Torunana, *et al.,* 1981). Wild (1972) reported that 0.01 M $CaCl_2$ and 0.001 M $CaCl_2$ were useful for estimation of available K in the Savanna soils of Northern Nigeria. Similarly, Ekpete (1972) compared various extractants for estimation of available K and reported that 0.01M $CaCl_2$ gave the best result followed by hot HNO_3 and cold 6N H_2SO_4 for Eastern Nigerian soils.

Swami and Lal (1970) found that the Morgan's solution provides a better estimate of available K to plants than five other extractants they tested. Habib *et al.,* (1986) found that NH_4OAc, NH_4Cl, H_2SO_4, HNO_3 and $CaCl_2$ gave very good correlations with plant uptake of K. Daudu *et al.* (2000) predicted available K for maize in Northern Nigerian soils using chemical extractants and found that the availability of soil pH is an interplay of secondary soil factors such as effective cation exchange capacity (ECEC) and soil reaction acting on the extractable forms. A simple correlation analysis they performed using all soil K tests excluding Morgan's solution (MS) were significantly correlated with K uptake by maize plants grown in a greenhouse.

The heterogeneity of soils should be considered in selecting the most suitable extractant for estimation of available K in soils because some soil characteristics influence the efficiency of the extractants, hence there is a need for determining the most suitable K extractant for estimation of available K in Edo State of Central Southern Nigerian soils.

Edo State of Central Southern Nigeria is located between Latitudes 5^0 4" and 7^0 38" North and Longitudes 5^0 4" and 6^0 31" East of the Equator. The area of the state is estimated to be about 19,035 km^2

Nine composite samples of soils from surface (0–15cm depth) and subsurface (15–30cm depth) were collected from pre-classified sites in Edo State of Central Southern Nigeria, as shown in Fig. 1 (Edo State Map). From a sampling site, 10 core samples were drawn from different points at 1m apart and bulked them together to form a composite soil sample.

The 9 composite surface and subsurface soil samples were air-dried and sieved through 2 mm sieve. The sieved soil samples were kept in closed plastic containers for subsequent use.

Four hundred gram of each of the composite soil was weighed into 500 ml capacity plastic pots. Ten ml solution containing N, P, Mg, S, B, Mn, Cu, Zn, Mo and Fe based on soil test were applied at the rate of 100, 50, 100, 30, 2, 10, 2, 10, 2 and 7.2 mgl^{-1} respectively. The respective fertiliser materials used were NH_4NO_3, H_3PO_4, $MgCl_2.6H_2O$, Conc. H_2SO_4, H_3BO_3, $MnCl_2.4H_2O$, $CuSO_4.5H_2O$, $ZnCl_2$(95 %), H_2MoO_4 and $FeSO_4.7H_2O$.

The soils were watered to field capacity with distilled water and allowed to equilibrate for 2 days. Six pre-germinated maize seed (DMR variety) were planted in each pot. The seedlings were thinned to 4 plants per pot after a week. The soils were kept moist with a solution of NH_4NO_3 (1.5g NH_4NO_3 in 5 *l* distilled water).

The ten portions of maize grown in above soils were harvested after four weeks of planting, oven dried at 70^{0}C for 24 hrs, weighed, ground and stored. Half a gram (0.5g) of each sample was digested with HNO_3, H_2SO_4 and $HClO_4$ acid mixture at 250^{0}C for 2h (Tan, 1996), and K concentration in the samples

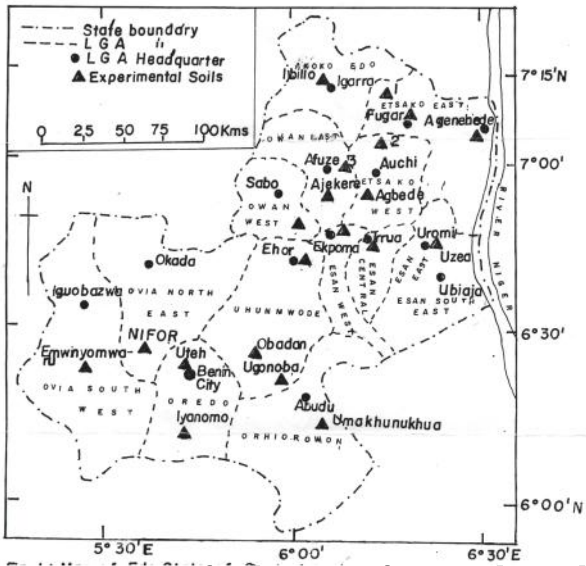

Figure 1: Map of Edo state of Central Southern Nigeria showing experimental soils

were determined using Jenway flame photometer.

Particle size distribution was done by hydrometer method (Bouyoucous, 1962). Soil pH was determined in soil-water suspension of 1:2 soil-solution ratio using a pH meter with glass electrode. Organic carbon was determined by wet dichromate acid oxidation method (Nelson and Sommers, 1982). Exchangeable bases (Ca, Mg, K and Na) were extracted using 1 N

Table 1: Physical and chemical properties of soil samples used for the study

S/No	Taxonomy (USDA)	Location	Soil depth (cm)	Clay	Silt	Sand	pH	C	OM	*Exchangeable bases*				*exchangeables*			
										Ca	Mg	Na	K	H^+	Al^{3+}	ECEC	BS
				←	%	→		← %	→ ←			cmol/kg				→	%
1.	Rhodic paleudult	National Institute for Oil Palm Research (NIFOR)	0 – 15	6.5	1.4	92.1	5.40	1.18	2.03	5.02	0.88	0.33	0.29	0.40	0.10	7.92	93.68
			15 – 30	13.5	0.4	86.1	4.70	1.22	2.40	3.68	0.96	0.34	0.21	1.40	0.70	7.29	71.19
2.	Rhodic paleudult	Uguonoba	0 – 15	10.5	1.9	87.6	4.60	0.29	0.30	1.12	0.16	0.34	0.81	2.20	1.40	6.03	40.29
			15 – 30	14.0	0.9	85.1	4.60	0.39	1.60	1.12	0.16	0.32	0.21	1.80	1.60	5.21	34.74
3.	Typic paleudult	Obayator	0 – 15	8.0	1.4	90.6	4.60	1.05	1.81	1.92	0.40	0.36	0.09	2.40	0.40	5.57	49.73
			15 – 30	8.0	1.4	90.6	4.50	0.67	1.16	1.20	0.40	0.33	0.10	2.60	1.40	6.03	33.66
4.	Lithic haplustalf	Sobe Ogbe	0 – 15	6.5	15.4	78.1	5.70	1.14	2.48	4.12	0.86	0.39	0.76	1.00	0.30	7.43	82.50
			15 – 30	11.0	16.9	72.1	6.00	0.48	0.83	4.94	1.72	0.40	0.60	1.20	0.50	8.86	80.81
5.	Typic tropaqualf	Agenebode	0 – 15	9.0	10.9	80.1	5.90	0.93	1.60	3.46	0.84	0.50	0.48	0.60	0.20	6.08	86.84
			15 – 30	3.0	2.4	94.6	5.90	0.58	1.00	3.12	1.20	0.50	0.23	0.50	0.10	7.13	90.18
6.	Gossarenic paleustalf	Fugar	0 – 15	6.0	1.4	92.6	5.80	0.86	1.43	6.46	0.24	0.38	0.27	0.90	0.50	8.93	84.32
			15 – 30	8.0	3.9	98.1	5.70	0.73	1.26	5.44	0.40	0.19	0.60	0.10	0.10	7.13	90.18
7.	Lithic troporthent	Manilla Forest	0 – 15	8.5	4.9	86.6	5.70	1.57	2.71	3.68	0.50	0.34	0.48	1.00	0.40	6.40	78.12
			15 – 30	10.5	6.9	82.6	5.80	1.31	2.26	4.74	0.93	0.49	9.42	0.70	0.20	7.51	88.01
8.	Rhodic paleudult	Ehor	0 – 15	6.5	1.9	91.6	5.50	1.89	3.26	2.44	0.96	0.46	1.00	0.70	0.30	5.86	82.92
			15 – 30	9.5	2.9	87.6	5.40	0.86	1.46	4.48	1.28	0.31	0.45	0.70	0.10	7.32	89.07
9.	Rhodic paleudult	Iruekpen	0 – 15	5.5	2.4	92.1	5.50	0.93	1.60	3.92	0.40	0.29	0.18	0.80	0.10	5.59	83.89
			15 – 30	8.0	1.4	90.1	5.60	0.77	1.33	5.28	1.04	0.29	0.14	0.70	0.20	7.65	88.23

Table 2: Amounts of K extracted from soil samples using different extractants and dry matter yield and K uptake by maize

S/No	Location	Depth	Distilled water	0.5 N $NaHCO_3$ (pH 8.5)	0.01 M $CaCl_2$	0.1 N HNO_3	1 N NH_4OAc	Dry Matter Yield	K uptake
		(cm)	←------	------	cmol/kg	------	------→	(g/pot)	(mg/pot)
1.	National Institute for Oil Palm Research (NIFOR)	0 – 15	0.065	0.103	0.069	0.076	0.112	0.70	2.604
		15 – 30	0.017	0.062	0.052	0.041	0.073	0.55	1.876
2.	Uguonoba	0 – 15	0.040	0.051	0.035	0.020	0.058	0.50	1.240
		15 – 30	0.009	0.031	0.017	0.003	0.010	0.60	1.302
3.	Obayator	0 – 15	0.009	0.014	0.013	0.005	0.010	0.75	2.093
		15 – 30	0.017	0.021	0.026	0.008	0.019	0.65	1.411
4.	Sobe Ogbe	0 – 15	0.117	0.134	0.069	0.186	0.253	1.50	8.370
		15 – 30	0.057	0.172	0.065	0.135	0.258	1.00	6.820
5.	Agenebode	0 – 15	0.430	0.148	0.065	0.105	0.238	1.00	5.580
		15 – 30	0.035	0.076	0.043	0.041	0.083	0.60	2.790
6.	Fugar	0 – 15	0.035	0.082	0.030	0.016	0.097	0.75	3.023
		15 – 30	0.004	0.041	0.061	0.018	0.073	0.75	3.472
7.	Manilla Forest	0 – 15	0.030	0.082	0.030	0.117	0.204	1.50	7.400
		15 – 30	0.017	0.050	0.022	0.082	0.170	1.45	7.192
8.	Ehor	0 – 15	0.048	0.120	0.082	0.099	0.185	0.65	4.232
		15 – 30	0.022	0.055	0.026	0.056	0.120	0.65	3.426
9.	Iruekpen	0 – 15	0.022	0.027	0.009	0.046	0.053	0.75	2.093
		15 – 30	0.022	0.027	0.004	0.018	0.068	0.65	2.418

NH_4OAc buffered at pH 7.0 (Thomas, 1982). Exchangeable K and Na contents of the extracts were determined using a flame photometer while exchangeable Ca and Mg were determined with the aid of atomic absorption spectrophotometer. Exchange acidity (Al^{3+} and H^+) was extracted with 1N KCl (Thomas, 1982) and determined by titrating with 0.05 N NaOH using phenolphthalein indicator. The effective cation exchange capacity (ECEC) was calculated by summation of exchangeable bases (Ca, Mg, K, Na) and exchange acidity. Percentage base saturation was calculated as the sum of exchangeable bases divided by ECEC and expressed as percentage.

The physical and chemical properties of the soils used for the study are shown in Table 1. The soils are more sandy in texture with low pH, organic matter and effective cation exchange capacity (ECEC).

The amounts of K extracted using various soils tests are shown in Table 2. The average concentration of available soil K extracted by different soils tests were found to decrease in the order of: 1 N NH_4OAc (pH 7) > 0.5 N $NaNHCO_3$ (pH 8.5) > 0.01 N HNO_3 > distilled water > 0.01 M $CaCl_2$. The results indicated that alkaline and strong mineral acids extracted more K. Hunter and Pratt (1957) attributed high K to high dissociation of $^{H+}$ in acids in

Table 3: Simple correlation coefficients between K extracted by the soil tests and soil properties

Soil properties	Distilled water	0.5 N $NaHCO_3$ (pH 8.5)	0.01 M $CaCl_2$	0.1 N HNO_3	1 N NH_4OAC (pH 7)
Clay	–0.0387	–0.1905	–0.1088	–0.1020	–0.0618
Silt	0.4612	–0.0601	0.4593	0.7823***	0.7872***
Sand	–0.4083	–0.1241	–0.2217	–0.6670**	–0.6655**
pH (H_2O)	0.3296	0.3299	0.3349	0.5730*	0.7062**
Organic Matter	0.0392	0.3316	0.2863	0.4791*	0.3884
Ex. H^+	–0.2153	–0.4567	–0.3703	–0.3543	–0.4500
Ex. Al^{3+}	–0.1864	–0.2828	–0.2273	–0.3831	–0.4225
ECEC	–0.0618	–0.0438	0.2342	0.2880	–0.3998
Base Saturation	0.2174	0.3935	0.3518	0.4587	0.5447

* =Significant at 5% level, **=Significant at 1% level, *** = Significant at 0.1% level

Table 4: Simple correlation coefficients among K extracted by the soil test methods

	Distilled water	0.5 N $NaHCO_3$ (pH 8.5)	0.01 M $CaCl_2$	0.1 N HNO_3	1 N NH_4OAC (pH 7)
Distilled H_2O	1	0.5852*	0.4131	0.4221	0.5340*
0.5N $NaHCO_3$ (pH 8.5)		1	0.4910*	0.1999	0.3613
0.01M $CaCl_2$			1	0.6039**	0.6172**
0.1N HNO_3				1	0.9375***
1N NH_4OA_c (pH 7)					1

* =Significant at 5% level, **=Significant at 1% level, *** = Significant at 0.1% level

water which facilitates exchange reactions in the soil.

The relationship between extracted soil K values of different chemical tests and soil physico-chemical properties are shown in Table 3. pH was positively and significantly correlated with available K values extracted by 0.1N HNO_3 (r = 0.373*) and 1N NH_4OAc (r = 0.7062**) respectively. The relationship with pH is strictly empirical as the pH of any soil is influenced by many factors (Russell and Russell, 1973). This association should be treated with caution because the range of pH observed for the soil was small (4.5 to 6.0). It has been suggested that this relationship of extractable soil K with soil pH might be due to the fact that the pH of a soil is often related to its base saturation (Acquaye, 1973). Daudu *et al.* (2000) also observed this relationship in their study.

The extractable soil K values with 0.1 N HNO_3 and 1 N NH_4OAc (pH 7) were also significantly and positively correlated with the silt content of the soil and negatively and significantly correlated with the sand content (Table 3). This may suggest that the efficiency of these two extractants are influenced by sand and silt content of the soil.

The extracted soil K values by other soil tests namely: distilled water, 0.5 N $NaHCO_3$ and 0.01M $CaCl_2$ were not significantly correlated with any of the soil properties (Table 3).

The degree of correlation among the soil tests are shown in Table 4. The coefficient of simple correlation indicated that the soil tests for K may be grouped into two. The first group consists of 0.1 N HNO_3 and 1 N NH_4OAc which were strongly inter-related with 'r' values greater than 0.9000. Distilled water, 0.5 N $NaHCO_3$ and 0.01 M CaCl-$_2$ constitute the second group with 'r' values less than 0.7000. The highest correlations were found in 0.1 N HNO_3 and 1 N NH_4OAc soil tests (r = 0.9375***). These two soil tests appeared to extract K from a wider pool of available K in the soils. Exchangeable K as determined by leaching with neutral NH_4OAc is the conventional method of determining the available K in Central Southern Nigeria. The relative degree of correlation of the soil tests values with exchangeable K values are indicated below: 1 N NH_4OAc (pH 7) > 0.1 N HNO_3 > 0.01 M $CaCl_2$ > Distilled water > 0.5 N $NaHCO_{3-}$ (pH 8.5).

The coefficient of correlation between the plant parameters and extractable K values of various extractants are shown in Table 5.

The data indicated that the relationships between the soil tests and plant K uptake were significant for all the soil tests except water. This indicates that distilled water is not a suitable extractant for evaluating K in these soils. The highest degree of correlation with plant K uptake was obtained with 1 N NH_4OAc fol-

Table 5: Simple correlation between extractable K extracted by the extractants and amount of K taken up by maize and the dry matter yield

Extractants	Shaking Time (min)	r	Uptake Regression Equation	r	Dry Matter Yield Regression Equation
Distilled water	15	0.336ns	Y = 3.30 + 8.00X	0.235ns	Y = 0.79 + 0.79X
0.5 N $NaHCO_3$ (pH 8.5)	15	0.579*	Y = 2.76 + 9.33X	0.591**	Y = 0.69 + 1.34X
0.01 M $CaCl_2$	60	0.526*	Y = 2.72 + 18.55X	0.128ns	Y = 0.76 + 1.74X
0.1 N HNO_3	15	0.893***	Y = 1.36 + 39.61X	0.754***	Y = 0.55 + 4.71X
1 N NH_4OA_c (pH 7)	15	0.910***	Y = 0.75 + 26.11X	0.718***	Y = 0.50 + 2.90X

ns=Not significant at 5% level, *=Significant at 5% level, **=Significant at 1% level, ***=Significant at 0.1% level lowed by 0.1 N HNO_3 both at 1% level of significance. The soil tests that appeared to have almost equal K extraction efficiency in soils were the 1 N NH_4OAc (pH 7) and 0.1 N HNO_3.

The soil tests also had positive and significant correlation with dry matter yield with the exception of distilled water and 0.01M $CaCl_2$ soil tests (Table 5). 1 N NH_4OAc (pH 7) and 0.1 N HNO_3 are recommended for estimation of available K in soils of Edo State of Central Southern Nigeria.

It is recommended to use 1 N NH_4OAc or 0.1N HNO_3 which are having almost equal efficiency in the estimation of available K in soils of Edo State of Central Southern Nigeria.

REFERENCES

Acquaye, D.K. (1973) Factors determining the K supplying power of soils in Ghana. *10th Colloguium on K in tropical crops and soils*, pp. 51 – 67

Bouyoucos, C.J. (1962) *Soil Sci. Soc. Amer. Proc.* 26: 464 – 465.

Daudu, C.K. *et al.* (2000) *Niger. J. Soil Res.* 1: 12 – 16

Hunter, A.H. and Pratt, P.F. (1957) *Soil Sci. Soc. Amer. Proc.* 21: 595 – 598

Nelson, D.W. and Sommers, L.S. (1982) Total carbon, organic carbon and organic matter. In: Page, A. L. *et al.* (eds), "Methods of Soil Analysis" Part 2. *Agron. Monogr.* 9 (2nd edition). Pp. 539 – 579. ASA and SS SA. Madison, Wisc

Russell, E.W. and Russell, E.J. (1973) In: *Soil Conditions and Plant Growth*, pp. 849, Longmans

Swami, B.N. and Lal, P.B. (1970) *J. Idian Soc. Soil Sci.* 18: 27 – 32

Tan, K.H. (1996) In: *Soil Sampling, Preparation and Analysis*. Marcel Dekker, Inc.

Thomas, G.W. (1982) Exchangeable cations. In: Page, A.L. *et al.* (eds), "Methods of Soil Analysis" Part 2. *Agron. Monogr.* 9 (2nd edition). pp. 159 – 165. ASA and SSSA. Madison, Wisc

Torunana, J.M.A. *et al.* (1981) *Niger. J. Soil Sci.* 1(4): 31 – 40