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POTASSIUM DISTRIBUTION IN THE SAND, SILT AND CLAY FRACTION OF SOILS DEVELOPED OVER TALC IN ODO-OGBE, KOGI STATE, NIGERIA

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ABSTRACT

Potassium (K) status of soils formed over talc at in a Southern Guinea Savanna Zone of Nigeria was assessed by the exchangeable, acid extractable, residual K and total K values in the sand, silt and clay fractions of the soils. Soil samples collected from genetic horizons of profile pits dug in five mapping units were fractioned into the three particle sizes of sand, silt and clay and exchangeable; acid extractable, residual K and total were determined in each particle size fractions. Result indicated that the total K was greater than 60 cmol kg^{-1} in all the profiles while HCl extractable K (reserved K) and HNO_3 extractable K (mobile K) ranged in values from 3.73 cmol kg^{-1} to 52.63 cmol kg^{-1} and 3.12 cmol kg^{-1} to 25. 57 cmol kg^{-1} respectively with exchangeable K accounting for less than 1% of the total K and ranged in value between 0.16 cmol kg^{-1} and 0.36 cmol kg^{-1}. In most cases, the clay fraction of the soils had similar values of all the forms of potassium with the silt fraction while the sand fraction had the least values of these forms of potassium. The high values of the different forms of K obtained in these soils may have been occasioned by the presence of degraded mica, interstratified (smectite/vermiculite), and interstratified mica-smectite with a high concentration of degraded mica in the soils. An assessment of the potassium status of the soils, using the K saturation index revealed that the level of potassium in these soils was adequate for the sustainable production of the dominant crops grown in the area of study.

INTRODUCTION

Potassium (K) has been reported as one of the limiting nutrients under intensive cropping with high yielding varieties (Ajiboye *et al*. 2000; Bansal *et al*. 2002). Bansal *et al*. 2002) noticed that those soils, which were considered sufficient in exchangeable K, were not able to maintain that condition for long under intensive cropping. This confirmed an earlier observation by Wild (1971), who stated that as cropping became more intensive, the drain on potassium will increase and the occurrence of K deficiency will likely become more widely spread in the soils of the savanna zone of Nigeria.

Apart from the dynamics of potassium in the soil usually evaluated by the quantity/intensity (Q/I) ratio of K (Akinrinde, 1999; Wang and Scott, 2001), the ability of any soil to maintain a reasonable productive K potential under intensive use with minimum external input of inorganic and organic fertilizer also depends on the inherent K status of the soil

(Bansal *et al*., 2002). Available K and K saturation index, defined as the ratio of exchangeable K to cation exchange capacity (CEC %) have been widely used for rapid assessment of the soil K status and prediction of crop K requirements (Wild 1971; Mutscher 1995; Samadi, 2006). However, recent research works (Bansal *et al*., 2002), showed that exchangeable K alone couldn't be used as the basis for evaluating K availability under intensive cropping because there are evidences of uptake of K from non-exchangeable form (Mengel, 1982) and continuous but slow transfer of potassium in the primary minerals to the exchangeable and slowly available forms of potassium (Sparks *et al.,* 1980; Kirkman *et al*., 1994; Sarkar *et al*., 2001; Bansal *et al*., 2002). Brar and Sekhon (1976), suggested that the level of non–exchangeable K in the soil could be used to determine the critical limit of K in the soil. Furthermore, Mukhopadhyay and Datta (2001), quoted Singh and Brar, in the soils of the Punjab, India's continuous cropping without K applications decreased the content of available K from 2.12 to 0.11 cmol kg^{-1}. Despite this, there was no response to applied K because 90 % of the K demand of the crop was met by K release from the non-exchangeable K pool. Similar findings were reported by Subba Rao *et al.* (2001), who showed that about 86% of the total K uptake by a wheat crop came from the non-exchangeable K pool.

Potassium fertility is characterized generally based on readily available K forms. However, many reports indicate the instances where available K based on NH_4OAc extraction is not sensitive to the changes in soil K that take place during cropping. Therefore, recently a trend is emerging on characterization of soil K based on non-exchangeable K fraction in soil (Srinivasarao *et al,* .2001). This study was therefore designed to evaluate the levels of the different forms of native (inherent) potassium in the particle size fractions of soils derived from talc in the Southern guinea savanna of Nigeria and to relate this to the sustainable use of the soils with low external inputs under intensive irrigation agriculture.

MATERIALS AND METHODS

The selected site is located on Latitudes 8^0 45'N and Longitude 5^0 45' E in the Southern guinea savanna agro-ecological zone of Nigeria. The area under study has been acquired for intensive irrigation agriculture. According to the Nigeria Geological Survey map (GSD, 2004), the site lies across two major rock groups; undifferentiated meta-sediments and undifferentiated basement complex. The site has commercial deposits of talc, with noticeable occurrences of granite-gneiss and quartz-schist as one move away from the talc deposit area. Rainfall in the research area generally begins in April and ends in October with a break of about two weeks occurring either in July or August. Annual rainfall ranges between 1200 mm and 1600 mm rainfall with a dry season occurring between November and March/April.

Field survey was conducted in the selected site (600 m by 1000 m) using the rigid grid systematic method with traverses cut at intervals of 50 m both in the vertical and horizontal directions at right angles (90^0) to each other and this resulted in the delineation of five mapping units. Soil profile pits were dug to represent each mapping unit and the soils samples, which were collected from genetic horizons of the profile pits, were air-dried, passed through 2mm sieve and fractioned into the three particle sizes of sand, silt and clay using the wet sieving and decantation method. The soil fractions were thereafter oven dried at 105^0C for 48 hours and ground to pass through a 100-mesh sieve (0.2mm) before being used for the determination of the different forms of potassium.

Nitric acid soluble potassium (Mobile potassium***)*** was obtained by extracting soil fractions with 1N Nitric acid (1N HNO_3) in 1: 10 soil – acid suspension with boiling for 10 minutes while the method of Piper (1950) was used in the extraction of Hydrochloric acid soluble Potassium. This extraction involves using a soil – acid ratio of 1:10 and boiling the suspension for 60 minutes. Total potassium was obtained by digesting the soils in a mixture of concentrated Nitric acid (HNO_3) and Perchloric acid ($HClO_4$) using a soil – acid ratio of 1: 10. Exchangeable potassium was extracted from the soils by normal ammonium acetate (1N NH_4OAc) buffered at pH 7. This fraction contained both the soluble and exchangeable forms of potassium but will be regarded in this paper as exchangeable potassium. Cation exchange capacity (CEC) was determined according to the procedure of Hossner (1970).

RESULTS AND DISCUSSION

Total Potassium

Table 1 shows the distribution of total K (K_t), reserved K (K_{res}), mobile K (K_{mob}), exchangeable K (K_{ex}) and residual K (K_{du}) in the three particle size fractions of sand, silt and clay respectively. The sand fraction of the soils had lower total K (K_t) values than the silt and clay fractions in all the horizons and profiles. The K_t values of the sand fraction ranged between 2.56 cmol kg^{-1} and 5.63 cmol kg^{-1} in the surface horizons while the subsurface horizons had values of K_t between 1.53 cmol kg^{-1} and 15.35 cmol kg^{-1}. In the silt fraction of the soils, the values of K_t ranged from 28.64 cmol kg^{-1} and 42.46 cmol kg^{-1} in the surface soils and from 25.58 cmol kg^{-1} to 51.66 cmol kg^{-1} in the subsurface soils. However, the values of K_t in the clay fraction ranged between 27.62 cmol kg^{-1} and 46.55 cmol kg^{-1} in the surface horizons while the subsurface soils had K_t values that ranged between 31.71 cmol kg^{-1} and 43.99 cmol kg^{-1}. The disparity between the K_t contents of silt and clay particle size fractions was not as high as that between silt and sand or clay and sand. In some cases, the values of the K_t content of the silt particle size fractions were even higher than those of clay size fractions and vice versa. The general trend of K_t in all horizons and profiles was clay ≈ silt > sand. The sum of K_t of silt and clay account for more than 90% of the K_t values of all the three fractions put together (i.e. K_t sand + K_t silt + K_t clay). This suggests that the clay and silt fractions of the soils may be more important in the study of the potassium supplying power of the soils developed over talc

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Table 1: Potassium distribution in three particle sizes of soils developed over talc overburden.

FIELD NO	DEPTH (cm)	Total K in Sand cmol kg^{-1}	Total K in Silt cmol kg^{-1}	Total K in Clay cmol kg^{-1}	Reserved K (HCl Extract) in Sand cmol kg^{-1}	Reserved K (HCl Extract) in Silt cmol kg^{-1}	Reserved K (HCl Extract) in Clay cmol kg^{-1}	Mobile K (HNO_3 Extract) in Sand cmol kg^{-1}	Mobile K (HNO_3 Extract) in Silt cmol kg^{-1}	Mobile K (HNO_3 Extract) in Clay cmol kg^{-1}	Exchangeable K (NH_4OAc) in Sand cmol kg^{-1}	Exchangeable K (NH_4OAc) in Silt cmol kg^{-1}	Exchangeable K (NH_4OAc) in Clay` cmol kg^{-1}	Residual K in Sand cmol kg^{-1}	Residual K in Silt cmol kg^{-1}	Residual K in Clay` cmol kg^{-1}
OD1-A1	0-10	2.56	31.71	27.62	0.72	10.64	19.64	0.41	5.88	15.14	0.04	0.11	0.14	1.8	20.96	7.84
OD1-A2	10 – 28	5.12	30.69	36.83	1.84	16.16	16.57	1.33	5.37	14.32	0.04	0.09	0.10	3.24	14.44	20.16
OD1-B1	28-45	11.76	33.76	40.92	3.48	18.21	22.1	2.97	9.00	13.09	0.07	0.10	0.11	8.21	15.45	18.71
OD1-B2	45-105	11.76	41.43	33.76	3.38	15.14	5.27	2.71	7.01	10.43	0.06	0.12	0.11	8.32	26.17	28.38
OD1-C	105-140	9.72	40.92	38.36	4.76	22.10	25.78	2.97	9.00	10.23	0.05	0.10	0.13	4.91	18.72	12.45
OD2-A	0-15	2.56	28.64	39.39	0.51	8.59	3.68	0.31	3.48	8.03	0.03	0.07	0.14	2.02	19.98	35.57
OD2-B1	15-43	2.56	33.76	32.23	0.82	10.23	11.36	0.41	4.40	6.91	0.04	0.07	0.12	1.70	23.46	20.75
OD2-B2	43-110	3.58	27.62	34.78	1.74	7.57	5.52	0.72	4.04	7.47	0.04	0.10	0.16	1.80	19.95	29.1
OD2-C	110-140	13.81	32.23	43.99	2.25	7.47	8.90	0.92	4.71	8.03	0.04	0.10	0.15	11.52	24.66	34.94
OD3-A	0-9	2.56	29.67	31.71	0.31	5.27	6.04	0.15	2.71	5.42	0.03	0.10	0.18	2.22	24.3	25.49
OD3-B	9-120	1.53	25.58	34.78	0.61	3.58	5.27	0.15	3.17	3.79	0.03	0.07	0.12	0.89	21.93	29.39
OD3-C	120-180	3.58	33.25	36.83	0.31	4.04	4.76	0.15	2.71	2.86	0.03	0.04	0.10	3.24	29.17	31.97
OD4-A	0-10	5.63	30.69	33.76	0.41	2.56	5.47	0.15	2.46	4.09	0.04	0.10	0.20	5.18	28.03	28.09
OD4-B1	10-30	2.56	41.43	36.83	0.26	1.89	3.79	0.10	1.74	2.71	0.03	0.07	0.11	2.27	39.47	32.93
OD4-B2	30-95	2.56	41.43	35.81	0.41	1.74	2.51	0.10	1.13	2.71	0.03	0.05	0.10	2.12	39.64	33.20
OD4-C	95-140	15.35	26.09	31.71	0.26	0.92	2.56	0.15	1.33	1.64	0.03	0.05	0.11	15.06	25.12	29.04
OD5-A1	0-14	3.58	29.67	46.55	0.26	6.04	8.70	0.15	4.30	7.06	0.03	0.10	0.24	3.29	23.53	37.61
OD5-A2	14-32	2.56	42.46	45.52	0.41	2.66	10.64	0.15	10.64	5.42	0.02	0.04	0.16	2.13	39.76	34.72
OD5-A3	32-51	4.09	32.23	43.99	0.92	4.04	6.09	0.15	2.56	3.89	0.03	0.04	0.14	3.14	28.15	37.76
OD5-B1	51-69	1.53	41.43	41.43	0.31	2.4	7.98	0.10	3.17	5.12	0.02	0.05	0.16	1.20	38.98	33.29
OD5-B2	69-97	2.56	37.34	39.9	0.31	2.76	8.70	0.10	2.46	4.19	0.02	0.05	0.13	2.23	34.53	31.07
OD5-C1	97-105	2.56	31.71	43.48	0.20	7.42	5.83	0.15	4.91	5.32	0.03	0.06	0.16	2.33	24.23	37.49
OD5-C2	105-180	7.16	51.66	42.46	2.66	9.31	8.39	1.18	5.42	3.89	0.02	0.07	0.16	4.48	42.28	33.91

Table 2: Cumulative Potassium distribution of soils developed over talc overburden.

Pedon	Depth	Sand	Silt	Clay	^1K_t	$^1K_{res}$	$^1K_{mob}$	$^1K_{ex}$	$^1K_{du}$	^2K_t	$^2K_{res}$	$^2K_{mob}$	$^2K_{ex}$	$^2K_{du}$
	(cm)	←	(%) →		←				Cmol kg^{-1}			→		
OD1-A1	0-10	87.60	9.00	3.40	61.89	31.00	21.43	0.28	30.61	64.58	32.38	22.65	0.35	31.85
OD1-A2	10 – 28	88.60	8.00	3.40	72.63	34.58	21.02	0.23	37.83	77.41	36.91	22.84	0.33	40.18
OD1-B1	28-45	88.60	6.00	5.40	86.45	43.79	25.06	0.27	42.39	93.44	47.41	27.72	0.43	45.60
OD1-B2	45-105	78.60	13.00	8.40	86.96	23.79	20.15	0.28	62.89	92.95	25.47	21.98	0.41	67.08
OD1-C	105-140	78.60	7.00	14.40	89.00	52.63	22.20	0.28	36.09	92.87	54.97	23.47	0.35	37.55
OD2-A	0-15	85.60	10.00	4.40	70.59	12.79	11.82	0.24	57.57	74.06	13.43	12.58	0.31	60.31
OD2-B1	15-43	77.60	10.00	12.40	68.54	22.4	11.71	0.23	45.91	74.65	24.44	13.08	0.39	49.82
OD2-B2	43-110	70.60	11.00	18.40	65.98	14.83	12.23	0.30	50.85	71.36	16.07	13.54	0.48	54.81
OD2-C	110-140	70.60	11.00	18.40	90.03	18.62	13.66	0.28	71.13	96.86	20.06	15.02	0.43	76.36
OD3-A	0-9	86.60	9.00	4.40	63.94	11.61	8.29	0.30	52.03	63.46	11.52	8.21	0.29	51.65
OD3-B	9-120	75.60	9.00	15.40	61.89	9.46	7.11	0.21	52.21	65.60	10.04	7.67	0.29	55.27
OD3-C	120-180	79.60	11.00	9.40	73.66	9.10	5.73	0.16	64.39	79.82	9.88	6.36	0.26	69.68
OD4-A	0-10	89.60	5.00	5.40	70.08	8.44	6.70	0.34	61.30	74.29	8.96	7.23	0.47	64.87
OD4-B1	10 – 30	90.20	4.40	5.40	80.82	5.93	4.55	0.20	74.68	86.68	6.37	4.98	0.30	80.01
OD4-B2	30-95	82.20	7.40	10.40	79.80	4.65	3.94	0.17	74.97	85.81	5.01	4.33	0.26	80.54
OD4-C	95-140	74.20	10.40	15.40	73.15	3.73	3.12	0.18	69.23	79.82	4.08	3.49	0.31	75.43
OD5-A1	0-14	84.20	9.40	6.40	79.80	14.99	11.51	0.36	64.45	83.86	15.77	12.28	0.47	67.62
OD5-A2	14-32	84.20	10.40	5.40	90.54	13.71	16.21	0.22	76.61	91.40	13.84	16.41	0.23	77.32
OD5-A3	32-51	83.20	12.40	4.40	80.31	11.05	6.60	0.20	69.05	81.14	11.17	6.69	0.21	69.76
OD5-B1	51-69	90.20	4.40	5.40	84.40	10.69	8.39	0.23	73.48	80.54	10.19	7.89	0.19	70.16
OD5-B2	69-97	84.20	7.40	8.40	79.80	11.76	6.75	0.20	67.83	82.69	12.20	7.07	0.24	70.26
OD5-C1	97-105	86.20	6.40	7.40	77.750	13.45	10.38	0.25	64.05	79.00	13.67	10.60	0.27	65.06
OD5-C2	105-180	76.20	7.40	16.40	101.28	20.36	10.49	0.25	80.68	104.95	21.11	10.99	0.30	83.54

[1]Determined by summation of the K values of the different particle sizes. [2] Determined from non separated soil sample

Cumulative total K was calculated for these soils by adding the total K in sand, silt and clay fractions and this was compared with the total K determined directly using the fine soil (intact soil). Similar compilation was done for the reserved-K, mobile – K, exchangeable –K and residual – K and the results are presented as table 2. Total K varied between 61.89 cmol kg^{-1} and 90.54 cmol kg^{-1} in the surface horizons and ranged from 61.89 cmol kg^{-1} and 101.28 cmol kg^{-1} in the subsurface soils. However, the value obtained from the fine soil was slightly higher than cumulative total K by less than one percent ranging between 63.46 cmol kg^{-1} and 91.40 cmol kg^{-1}.

There are wide variations in the values of total K that have been reported for the soils of Nigeria. These variations resulted from the differences in the parent materials from which the various soils were derived. For instance, Udo and Ogunwale (1978), working on soils derived from basaltic, sedimentary and basement complex parent materials reported total K that ranged between 600ppm and 14,663 ppm (1.53 cmol kg^{-1} and 37.50 cmol kg^{-1}) in the surface soils and from 575ppm to 14,271ppm (1.47 cmol kg^{-1} to 36.50 cmol kg^{-1}) for the subsurface soils. These soils were distributed within three ecological zones (rain Forest, Derived savanna and Northern guinea savanna) of Nigeria. The soils developed on basalt and found in the Northern guinea savanna had the highest values of total K than the soils developed on basement complex found in the region of high rainfall (rain forest), although both basalt and basement complex contains K-feldspar and micaceous minerals in high quantity (Udo and Ogunwale 1978). Also, Wild (1971), worked on 31 soils from the savanna zone of Nigeria. He reported total K variation between 0.06 % and 3.99% (1.53 cmol kg^{-1} and 102.05 cmol kg^{-1}) and concluded that the soil content of total K depended on the nature of parent material from which the soil was formed. He discovered that the soils derived from basement complex had an average of 2.18% (55.75 cmol kg^{-1}), with a wide range between 0.35% and 3.99% (8.95 cmol kg^{-1} and 102.05 cmol kg^{-1}). However, soils derived from Nupe and false bedded sandstones had values of total K that ranged between 0.06% and 0.11% (1.53 cmol kg^{-1} and 2.81 cmol kg^{-1}). Adegbite (1993), working on the soils derived from Nupe sandstone in Kwara and Kogi states in the guinea savanna zone of Nigeria also reported total K values that ranged between 1.34 cmol kg^{-1} and 1.94 cmol kg^{-1} in the surface soils and a range of 0.12 cmol kg^{-1} to 1.88 cmol kg^{-1} in the subsurface soils. The values of total K obtained in this present studies were similar to those obtained by Wild (1971) and Udo and Ogunwale (1978) for soils developed on basement complex and basalts. However, the values of total K observed in the soils were higher than those obtained by Wild (1971) and Adegbite (1993), for soils developed from Nupe and False bedded sandstones. It therefore seems that these soils contained appreciable quantities of K-bearing minerals especially mica and feldspar than those of soils formed over sandstones.

Reserved Potassium

The potassium reserve (K_{res}) (Table 1) is the K extracted with 1N HCl with 60 minutes boiling according to the procedure of Haylock (1956). The values of K_{res} in the sand fractions ranged between 0.26cmol kg^{-1} and 1.84 cmol kg^{-1} in the surface horizons while the subsurface horizons had values of K_{res} between 0.20 cmol kg^{-1} and 4.76 cmol kg^{-1}. The silt fraction had higher values of K_{res} than the sand fractions and had K_{res} values that ranged between 2.56cmol kg^{-1} and 16.16 cmol kg^{-1} in the surface soils and between 3.58 cmol kg^{-1} and 22.10 cmol kg^{-1} in the subsurface soils. In the clay fraction however, the soils had K_{res} in the surface soils that range between 3.68cmol kg^{-1} and 19.64 cmol kg^{-1} while the subsurface soils had values of K_{res} between 2.51 cmol kg^{-1} and 25.78 cmol kg^{-1}. Generally, in all the profiles, the average K_{res} values were highest in clay followed by silt and least in sand (clay>silt>sand). Also, it was observed that the values of K_{res} were lower than those of total K (K_t) and residual K (K_{du}) in corresponding particle size fractions, horizons and profiles but higher than the values of exchangeable K (K_{ex}). However, the relationship between K_{res} and K_{mob} (mobile K) was inconsistent. Sometimes the values of K_{res} were higher those of K_{mob} while in some other instances the value of K_{res} were lower than those of K_{mob} in the corresponding particle size fractions, horizons and profiles.

Values of cumulative reserved K ranging between 5.93 cmol kg^{-1} and 34.58 cmol kg^{-1} were recorded in the surface soils while the subsurface soils had values that varied from 3.73 cmol kg^{-1} to 52.63 cmol kg^{-1}. Similar to K_t, the K_{res} values obtained from the fine soil (whole soil) was higher than the cumulative K_{res} value by less than one percent.

Reserved K constitutes a major part of the total non-exchangeable potassium which is released under intensive cropping and the degree of sufficiency of K for crop uptake depends on the level and ease of release of K from the K reserves of the soils (Udo and Ogunwale 1978). Udo and Ogunwale (1978) reported reserved K values between 308ppm and 585 ppm (0.79 cmol kg^{-1} and 1.50 cmol kg^{-1}) for the surface soils and ranges of 308ppm--1105pp (0.79 cmol kg^{-1} and 2.83 cmol kg^{-1}) for the subsurface soils of the soils, which they studied. These authors reported that the reserved K constituted between 3% and 43% of the total K. Adegbite (1993), however, reported reserved K values that varied from 0.56 cmol kg^{-1} to 0.92 cmol kg^{-1} and from 0.09 cmol kg^{-1} and 0.88 cmol kg^{-1} respectively for the surface and subsurface soils of soils derived from Nupe sandstone. The values of cumulative reserved K recorded in this study were consistently higher than those reported by Udo and Ogunwale (1978) and Adegbite (1993), both in the surface and subsurface soils. This may have resulted from the differences in the quantities of K-bearing minerals between the parent materials of the soils under study and those reported by Udo and Ogunwale (1978) and Adegbite (1993). The occurrence of appreciable quantities of reserved K in these soils could be an indication that the soils will be able to maintain adequate supply of K to crops under intensive cropping.

Mobile potassium

Mobile potassium (K_{mob}), which is generally regarded as the K-supplying power of the soil, refers to the K extracted with 1N HNO_3 with 10 minutes boiling. The distribution of mobile K in the soils under study was such that the K_{mob} in sand<silt<clay. The surface soils had K_{mob} values that ranged between 0.10 cmol kg^{-1} and 1.33 cmol kg^{-1} while the subsurface soils had K_{mob} values that varied from 0.10 cmol kg^{-1} to 2.97 cmol kg^{-1} in the sand fractions. The K_{mob} values in the silt fractions of the surface soils ranged between 1.74 cmol kg^{-1} and 10.64 cmol kg^{-1} while the subsurface soils had values of K_{mob} that varied from 1.13 cmol kg^{-1} to 9.00 cmol kg^{-1}. The clay fraction had higher K_{mob} values than those of silt and sand in most cases. These values ranged in the surface soils between 2.71 cmol kg^{-1} and 15.14 cmol kg^{-1}, while the subsurface soils had values between 1.64 cmol kg^{-1} and 13.09 cmol kg^{-1}. Cumulative mobile K values ranged from 4.55 cmol kg^{-1} to 21.43 cmol kg^{-1} in the surface soils while the subsurface soils had values that varied from 3.12 cmol kg^{-1} to 25.06 cmol kg^{-1}.

The values of mobile K reported in these soils were higher than those reported by Udo and Ogunwale (1978), Unamba- Opara (1985) and Adegbite (1993). Udo and Ogunwale reported mobile K values that ranged between 60 ppm and 264 ppm (0.15 cmol kg^{-1} and 0.68 cmol kg^{-1}) in the surface soils and values that varied from 29 ppm to 391ppm (0.07 cmol kg^{-1} to 0.68 cmol kg^{-1}) in the subsurface soils of the six soil series that they studied. Unamba - Oparah (1985), on the other hand reported values of mobile K that varied from 0.03 cmol

kg^{-1} to 0.31 cmol kg^{-1} for the soils of Northern Imo, while Adegbite (1993), reported values of mobile K that ranged between 0.08 cmol kg^{-1} and 1.65 cmol kg^{-1} for soils developed on Nupe sandstone in Abugi, Shonga and Lafiagi. The soils of Northern Imo (Unamba – Oparah, 1985) were described as "light textured", indicating that the soils were sandy. The soils that Adegbite (1993), studied were "light to medium" textured. The soils on which Udo and Ogunwale (1978), carried out their research cut across all the textural classes from light to heavy textured soils. However, the values of mobile K reported by these authors were similar only to the values of mobile K recorded in the sand fraction of the soils of under study. The combined data of these authors resulted in values of mobile K that ranged between 0.03 cmol kg^{-1} and 1.65 cmol kg^{-1} whereas the values of mobile K in the sand fraction of the soils under study varied from 0.10 cmol kg^{-1}--8.29 cmol kg^{-1}. This observation may have been caused by a higher content of K – bearing minerals in talc than in the banded gneiss, granite, basalt, coastal plain sand and Nupe sandstones from which the soils studied by these authors were developed. Previous studies showed that the dominant clay minerals of these soils were kaolinite, degraded mica, interstratified smectite/vermiculite, and interstratified mica-smectite with a high concentration of degraded mica and quartz. Detectable traces of feldspar and goethite also occurred in some of the pedons (Ajiboye *et al*, 2008).

Exchangeable Potassium

Exchangeable potassium is the immediate source of K supply to plants. The data obtained from this present study showed that the clay fraction of the soils contained more exchangeable K than either the silt or sand fractions of the soils. This observation was consistent for all the horizons and pedons. The values of exchangeable K in the sand fraction varied from 0.03 cmol kg^{-1} to 0.04 cmol kg^{-1} in the surface and ranged between 0.02 cmol kg^{-1} and 0.07 cmol kg^{-1} in the subsurface soils. The values of exchangeable K in the silt fraction of ranged between 0.07 cmol kg^{-1} and 0.11 cmol kg^{-1} in the surface and varied from 0.04 cmol kg^{-1} to 0.12 cmol kg^{-1} in the subsurface soils. Exchangeable K in the clay fraction had values that ranged between 0.14 cmol kg^{-1} and 0.24 cmol kg^{-1} in the surface and varied from 0.10 cmol kg^{-1} to 0.16 cmol kg^{-1} in the subsurface soils.

Unamba - Oparah (1985), quoting the works of Pagel *et al.*, (1968) and Haylock (1956) graded the potassium status of the soils of Northern Imo into three fertility categories based on the values of mobile K of those soils. These categories were K – deficient soils (mobile K < 0.31 cmol kg^{-1}), soils with moderate K (mobile K between 0.31 cmol kg^{-1} and 0.49 cmol kg^{-1}) and soils with adequate K (mobile K > 0.49 cmol kg^{-1}). The author concluded that only the soils that were deficient or moderate in K were those that will respond to applied K fertilizer. In a similar vein, Udo and Ogunwale (1978), also adopted the value of mobile K (0.3 cmol kg^{-1} and 0.64 cmol kg^{-1}) used by Ekpete (1972) in evaluating the potassium status of the soils that they studied. They were quick however, to point out that the critical level of mobile K that would provide adequate supply of K depends on the soil and the crop grown.

Residual potassium

While the total K content of the soil reflects the nature and degree of weathering of the parent material, the residual K is regarded as the structural K in the K-bearing minerals (Udo and Ogunwale, 1978). The residual K represents the difference between total K and the sum of exchangeable K and the K extracted by 1N HCl (reserved K). The amounts of this form of K in the three particle sizes were generally high with the distribution pattern being similar to that of total K. The residual K accounted for 50 % to 95% of total K (Tables 1 and 2). Values of residual K in these soils ranged between 30.61 cmol kg^{-1} and 64.45 cmol kg^{-1} in the surface soils with a variation of 36.09 cmol kg^{-1} and 80.18 cmol kg^{-1} in the subsurface soils. The residual K in these soils was partitioned in such a way that the clay fraction contained the highest quantity followed by the silt fraction while the sand fraction had the least content of residual K.

Reported values of residual K varied from 0.8 cmol kg^{-1} to 35.72 cmol kg^{-1} (330 ppm to 13,969 ppm) for different parent materials in the three major ecological zone of Nigeria (Udo and Ogunwale, 1978). Adegbite (1993), however, reported residual K value that varied from 0.21 cmol kg^{-1} and 0.81 cmol kg^{-1} in the surface soils and values which ranged between 0.20 cmol kg^{-1} to 0.89 cmol kg^{-1} in the subsurface soils of soils developed on Nupe sandstone. In this present study, the values of residual K were significantly higher than those reported by earlier authors. Again, these differences may have been occasioned by the presence of degraded mica, interstratified (smectite/vermiculite), and interstratified mica-smectite with a high concentration of degraded mica in these soils.

Evaluation of the potassium status of the soils

The potassium status of the soils under study was evaluated using the concept of the degree of potassium saturation (vK%) index. The vK% index is the ratio of exchangeable potassium divided by the cation exchange capacity of the soil multiplied by 100 (Unamba – Oparah, 1985; Adegbite, 1993) These soils (Fig. 1) exhibited 0% vK% range of 1% to 2%, 21.74% vK% range of 2% to 4% and the remaining 78.27% of the samples showed vK% greater than 4%. Also the data showed that 0% of the surface soils (A horizon) and 21.74% of the subsurface soils (B and C horizons) had vK% values that ranged between 2% and 4% while 21.74% of the surface and 78.27% of the subsurface horizons revealed ranges of more than 4% vK%.

The A horizons that exhibited only 0% vK% ranges of 1% to 2%, 2% to 4% but had 21.74% vK% greater than 4%. This shows that there was rapid movement of K from the A horizons to the lower horizons. The B-horizons on the other hand, had 43.49% vK% range greater than 4%, 13.04% vK% range between 2% and 4% and 0% vK% range between 1% and 2%. This also showed that the B-horizon horizons were also losing K to the lower C-horizons. The C-horizon had 13.04% vK% greater than 4% and exhibited only 8.70% and 0% vK% ranged between 2% and 4% and 1% to 2% respectively. Since there were losses of K both by the A and B-horizons, one would expect the accumulation of the losses from A and B-horizons in the C-horizons. This present analysis however did not show evidence of K accumulation in the C-horizon. However, an assessment of the soils using an index of exchangeable K over total K indicated that pedons OD2 and OD5 had clear zones of K truncation and accumulation (Fig. 2). Pedons OD4 and OD1 also had clear zone of K truncation but no zone of K deposition, while pedon OD3 showed continual loss of K to lower horizons. The above index further confirmed the downward movement and accumulation of potassium in the soils.

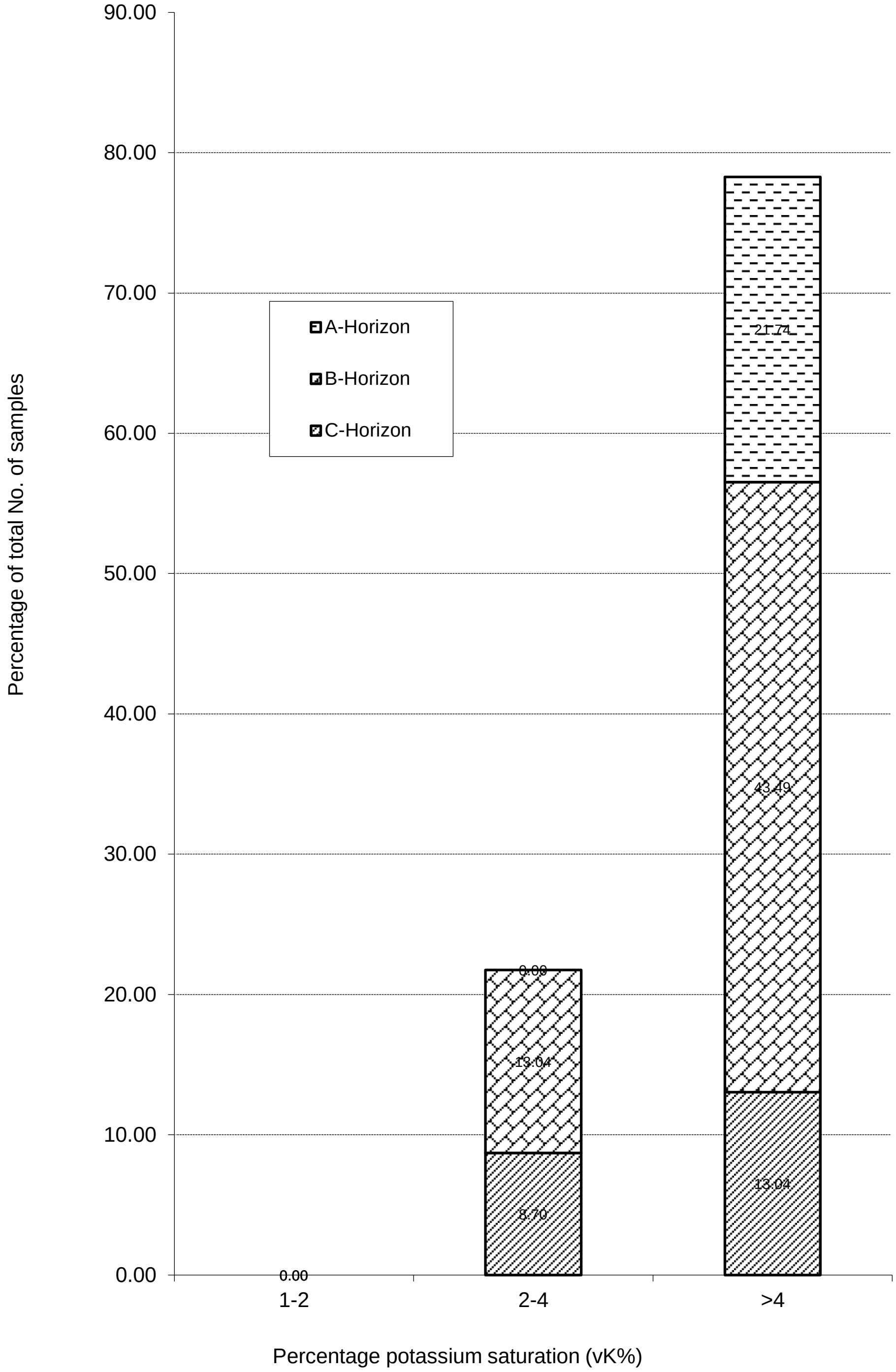

Fig. 1: Frequency distribution of percentage potassium saturation (vK%) in Odo- Ogbe

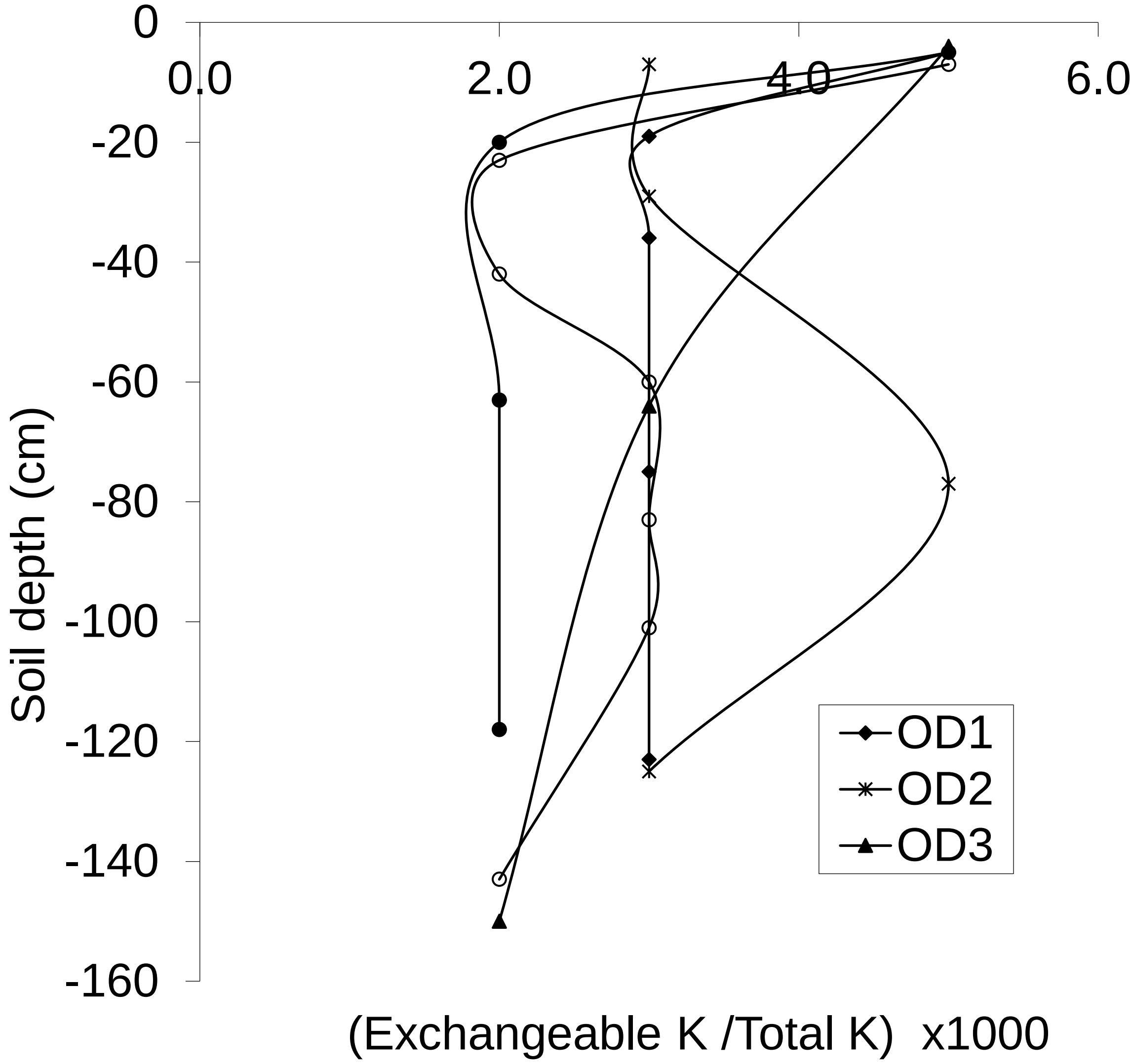

Fig.2: Depth functions of K_{ex}/ K_t in Odo-Ogbe soil

Table 3: Correlation co-efficient (r) values between the different forms of K in the soils.

	KT	KRES	KMOB	KEX	KDU	SAND	SILT	CLAY
KT	1.000							
KRES	-0.713**	1.000						
KMOB	-0.011	0.210	1.000					
KEX	-0.382	0.497*	0.820**	1.000				
KDU	0.927**	-0.722**	0.082	-0.339	1.000			
SAND	0.357	-0.006	0.627**	-0.657**	0.349	1.000		
SILT	-0.901**	0.637**	-0.079	0.321	-0.932**	-0.359	1.000	
CLAY	-0.448*	0.402*	-0.109	0.270	-0.595**	-0.183	0.373	1.00

KT = total K, KRES = reserved K, KMOB = mobile K, KEX = exchangeable K, KDU = residual K; * = significant at 5% probability level, ** = significant at 1% probability level.

A linear correlation analysis between the different forms of K and the soil particle size separates (Table 3) indicated that the total K (K_t) had significant and positive correlation with residual K (K_{du}) ($p<0.01$) but had negative and significant relationship with reserve K (K_{res}), the percentage silt ($p<0.01$) and clay ($p<0.05$) content of the soils. Similarly, the residual K which was positively correlated with total K had a significant and negative relationship with reserve K, silt and clay ($p<0.01$) content of the soils. Reserve K on the other hand had significant and positive correlation with exchangeable K (K_{ex}), silt ($p<0.01$) and clay ($p<0.05$) content of the soils while the mobile K (K_{mob}) was similarly significantly and positively correlated with exchangeable K ($p<0.01$). This shows that the more the silt and clay contents of these soils the higher quantity of K in the soils and the more dynamic is the K exchange equilibrium in the soil (Bansal, 2000). Bansal (2000), indicated that among the different textural classes in the same soil, the finer textured samples, generally contained more amounts of different forms of K and that both NH_4OAc-K and HNO_3 extractable K increased with heaviness. However, while mobile K was positively and significantly correlated with the percentage sand content of the soils, exchangeable K was negatively and significantly related to the sand content of the soils ($p<0.01$).

A positive and significant correlation obtained in this study between mobile K and exchangeable K (r= 0.82) confirms the earlier observation by Udo and Ogunwale (1978) and Ekpete (1972).

Mobile K is regarded as the K-supplying power of the soil (Udo and Ogunwale, 1978). It is a measure of the capacity factor, which in turn is an index of the potential K reserve of soils. From the ongoing, the mobile K status of the soils appears to indicate adequacy in its supply of K for the needs of plants under intensive cropping.

CONCLUSION

The general trend of the different forms of K in all horizons and profiles was clay ≈ silt > sand. The sum of the K of silt and clay account for more than 90 % of the K values of all the three fractions put together. This suggests that the clay and silt fractions of the soils may be more important in the study of the potassium supplying power of the soils developed over talc.

The higher values of the different forms of K obtained in this study over those obtained from previous studies in the savanna ecology of Nigeria may have been caused by the higher content of K – bearing minerals in these soils than in the banded gneiss, granite, basalt, coastal plain sand and Nupe sandstones from which the other soils were developed. This indicates that the mineralogy of these soils had significant influence on the K supplying power of the soils.

From the various parameters used in assessing the K status of the soils, these soils appear to have adequate potentials to supply sufficient quantity of K under intensive agriculture.

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