Forms and Distribution of Potassium in Red Laterite Soils of Patigi in North Central Nigeria

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Abstract

The study evaluated the forms and distributions of potassium in red laterite soils. Top soils samples 0 – 30cm, were randomly collected from thirty different major agricultural areas across Patigi LGA of Kwara State. Descriptive statistics was performed while regression analysis was used to assess the correlation between potassium forms. Results showed the exchangeable sodium (Na^{+}) was very low to moderate. The values ranged from 0.00 – 0.27 cmol/kg soil. The exchangeable potassium (K^{+}) of the soils is very low with values of 0.11 – 0.30 cmol/kg. Calcium (Ca^{2+}) values ranged between 0.10 and 5.1cmol/kg soil while magnesium (Mg^{2+}) ranged from 0.1 – 2.9 cmol/kg soil. The total potassium (K) obtained by concentrated perchloric acid ($HClO_4$) had higher values (3.1 – 11.0 cmol/kg of soil) than other potassium types studied. The available potassium (K) was positively and significantly correlated with HCl Extractable K^{+} (r = 0.98); HNO_3 Extractable K^{+} (r= 0.93) and $HCl0_4$ Extractable K^{+} (r=0.90) at P<0.01. The values of the extractable potassium increased in the order of NH_4OAC <HCl< HNO_3< $HClO_4$. The study revealed that Patigi soils are quite low in available K^{+} content thus, the supplying power of potassium in these soils is low, hence the need for potassium fertilization for a sustainable crop production.

Keywords: Forms, Distribution, Potassium, Red laterite soils, Patigi.

Introduction

Potassium (K) is considered an important element in soils. This essential nutrient is perceived to be next to nitrogen (N) in terms of plant nutrient requirements and is strongly involved in assimilation, phloem loading and transportation through xylem Mengel and Kirkby, (2001). Plants require potassium for a number of functions vis a vis; translocation of sugars, starch production in grains, nitrogen fixation in legumes and protein synthesis. It has been reported that K has a role in the process of folding and unfolding of stomata and in regulation of guard cells' osmotic activities (Dietrich et al., 2001). Furthermore, K also influences enzymatic processes and ATP synthesis. For this reason, plants suffering from K deficiencies are strongly affected by droughts. In addition, one key beneficial property of K in plants is its high tolerance of low temperatures leading to an improved protection against frost injury and winterkill (Wang et al., 2013).

Potassium positively affects disease resistance of crops (Oborn et al., 2005). It has been reported to have an important role in N_2-fixing legumes such as red clover. Also, adequate sward legume content was achieved when the legumes have sufficient plant-available K during the growing season Romer and Lehne (2004). This is because N_2 -fixing bacteria need an ample supply of potassium for efficient functioning (Johnston, 2003).

Over the years, crop yields have not been commensurate with the level of soil inputs in Patigi LGA probably because of inherent factors relating to soil nutrients especially potassium deficiency in the area among other constraints. This could be attributed to an overestimation of plant-available K as the solution K obtained from the most widely used method of extracting K can be easily leached and unavailable during wet period for plant uptake (Carrow *et al*., 2001).

Various extractants (dilute mineral acids, exchangeable K and dilute $CaCl_2$) (Mohammed, 2006) have been used in Kwara State soils, with the hot N HNO_3 the most effective compared with the neutral (pH 7.0) 1M NH_4OAc (ammonium acetate) which is the most widely used for extracting K.

The choice of extractant employed, however, is established from correlation between amounts extracted and crop growth/ yield (Affinnih *et* al., 2014). While the former removes exchangeable K on soil CEC sites as well as solution K, the latter would also replenish non exchangeable K from the exchange sites. Inspite of the higher correlation value which gives a better assessment of plant available soil K especially in soils with high total salts (Affinnih *et al*., 2014, Ogunwale and Mohammed, 2006) from hot $HNO_{3,}$ research on solution and exchangeable K replenished by nonexchangeable K is scarce. Therefore, the main objective of this study is to assess the distribution of total and available potassium in red laterite soils of Patigi in North Central Nigeria.

Materials and Methods

The study location

The study location: The study was conducted at the Agronomy Department Laboratory, Faculty of agriculture, University of Ilorin, Ilorin, Nigeria. Soil samples were collected in Patigi LGA of Kwara State, North Central Nigeria.

The area (2925sq.km) which has about 5% of total land area of the State, is located between latitude 8.50 and 9.00 North and longitude 5.60 and 6.00 East. Humid climate prevails which is characterized by wet and dry seasons, each lasting for about six months. Total annual rainfall is between 800 and 1200 mm while the temperature is between 30^{o}C and 35^{o}C.

Table I. *Showing GPS coordinates of the agricultural villages used for this investigation*

S/N NAME OF TOWN/ VILLAGE	DISTRICT LATITUDE	GPS COORDINATES LONGITUDE	
1 Esanti	Lade	8^0 44’ 11”	5^0 28’ 48”
2 Lata Nna	Lade	8^0 41’ 01”	5^0 28’ 26”
3 Sunkusu	Lade	8^0 47’ 56”	5^0 43’ 33”
4 Gada Maagin	Lade	8^0 35’ 58”	5^0 39’ 44”
5 Ndanaku	Lade	8^0 34’ 50”	5^0 30’ 16”
6 Sakpefu	Lade	8^0 49’ 00”	5^0 36’ 04”
7 Rani Ndako	Lade	8^0 45’ 31”	5^0 39’ 16”
8 Chenegi	Lade	8^0 48’ 44”	5^0 35’ 47”
9 Lade	Lade	8^0 45’ 32”	5^0 37’ 01”
10 Lalagi	Lade	8^0 49’ 51”	5^0 31’ 10”
11 Likofu	Patigi	8^0 43’ 24”	5^0 42’ 53”
12 Patigi	Patigi	8^0 43’ 29”	5^0 45’ 18”
13 Gbaradog	Patigi	8^0 44’ 15”	5^0 45’ 14”
14 Gbadokin	Patigi	8^0 43’ 31”	5^0 47’ 45”
15 Ragada	Patigi	8^0 43’ 39”	5^0 43’ 04”
16 Godewa	Patigi	8^0 44’ 38”	5^0 44’ 09”
17 Tswatagi	Patigi	$8^0$39’ 36”	5^0 47’ 39”
18 Ellah	Patigi	8^0 46’ 32”	5^0 45’ 10”
19 Mawogi	Patigi	8^0 44’ 28”	5^0 50’ 41”
20 Esungi	Patigi	8^0 43’ 40”	5^0 48’ 09”
21 Mamba	Kpada	8^0 36’ 48”	5^0 56’ 08”
22 Rogun	Kpada	8^0 38’ 49”	5^0 55’ 13”
23 Egboro	Kpada	8^0 31’ 32”	5^0 41’ 58”
24 Zhituala	Kpada	8^0 37’ 21”	5^0 48’ 23”
25 Kpada	Kpada	8^0 44’ 31”	5^0 28’ 48”
26 Gulugi	Kpada	8^0 44’ 03”	5^0 46’ 35”
27 Echiwada	Kpada	8^0 42’ 01”	5^0 56’ 36”
28 Gakpan	Kpada	8^0 41’ 32”	5^0 38’ 58”
29 Koro	Kpada	8^0 08’ 42”	5^0 30’ 39”
30 Kusogi	Kpada	8^0 43’ 02”	5^0 42’ 47”

Soil sampling and processing

Top soils, 0-30cm, from thirty agricultural areas of Patigi LGA were randomly sampled using soil auger. Twenty auger borings were collected from each area to form the composite sample. The samples were air dried for 3 days, ground, sieved and stored in labeled bags for laboratory analysis.

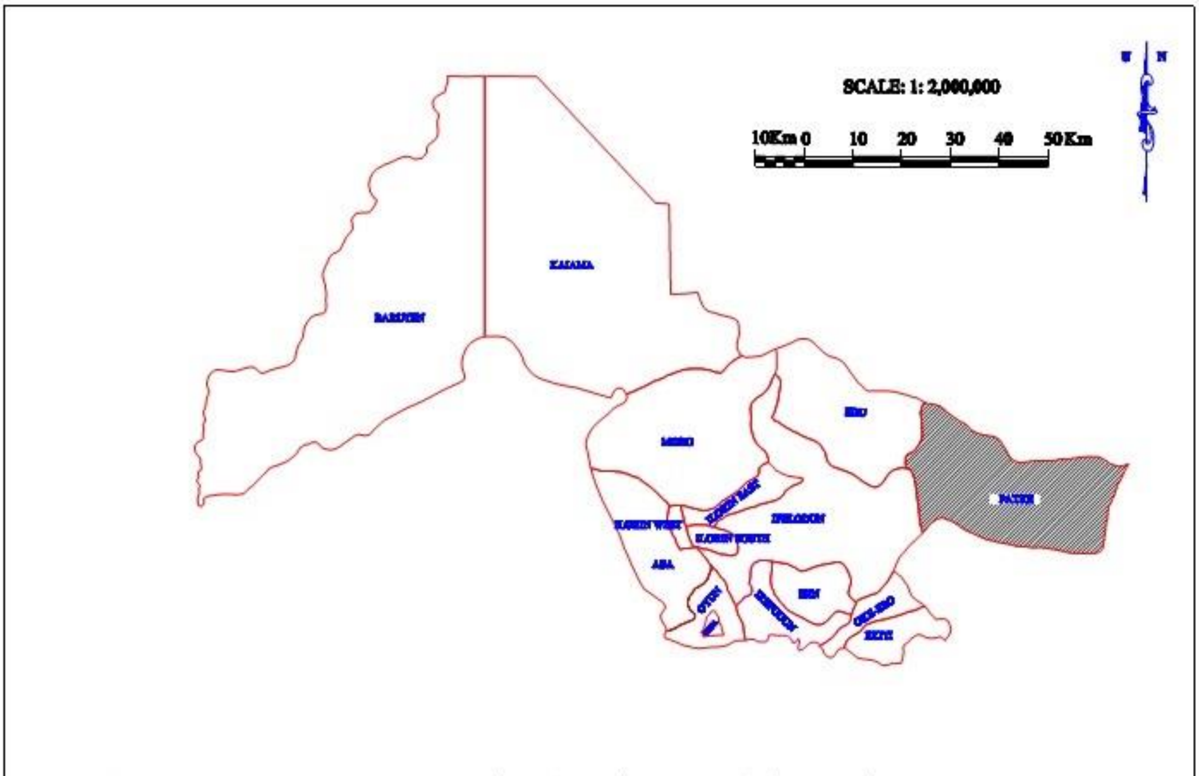

Fig 1: Map of Kwara State showing the sampled Local Government Area

Figure 1. *Map of Kwara State showing the sampled Local Government Area (Patigi)*

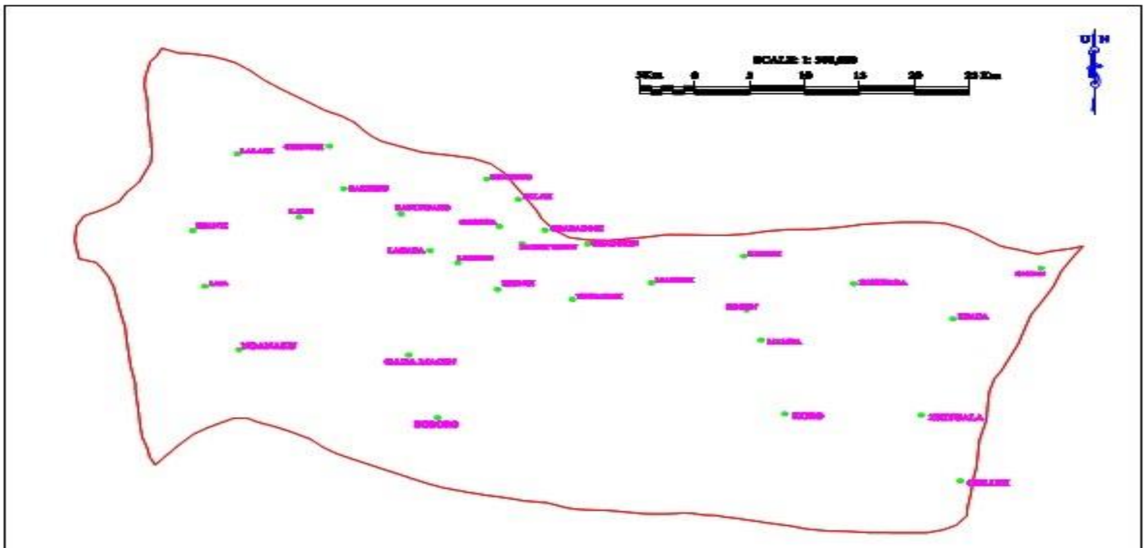

Fig 2: Map of Patigi LGA showing the locations of soil samples used in this investigation

Figure 2. *Map of Patigi LGA showing the locations of soil samples used in this investigation*

Basic exchangeable cations determination

A 5g of representative sample was weighed into sample bottle containing 50ml of 1N neutral ammonium acetate NH_4OAc solution. The mixture was shaken for 1 hour after that the content of the bottle was left to equilibrate overnight. Afterward the content was filtered through a Whatman No 42 filter paper into another bottle (Walkley and Black; Jackson 1973). The filtrate was used for the determinations of Na^+ and K^+ by flame photometry, while Ca^{2+} and Mg^{2+} combination were verified by versenate titration method using Erichrome black T as the indicator. Ca^{2+} alone was determined by versenate titration method using calcon as the indicator. The concentration of the cations were calculated after due note of the dilution factors and expressed in cmol. kg-1 soil (Walkley and Black; Jackson 1973).

Determination of calcium and magnesium (Ca+Mg)

A 5ml of the extract was pipetted into a 100ml capacity conical flask, then 5ml of concentrated ammonium hydroxide NH_4OH, 5 drops of 10% hydroxylamine hydrochloride, 5drops of 5% sodium cyanide and 3 drops of Erichrome black T indicator added. This was titrated against 0.02N EDTA. Colour change was observed from colorless to blue at the end point (Walkley and Black, Jackson 1973).

Determination of calcium (Ca)

A 5ml of the extract was pipetted into a 100ml capacity conical flask. 5ml of 20% sodium hydroxide (NaOH) was added and thereafter the following indicators were added; 5 drops of 10% hydroxylamine hydrochloride; 5 drops of 5% sodium cyanide and 3 drops of calcon. The mixture was titrated against 0.02N EDTA. At the end point, the colour changed from pink to light blue (Walkley and Black, Jackson 1973).
Calculation:

Determination of Na and K

The exchangeable Na^+ and K^+ were determined by flame photometry using soil extracts. The standards of Na^+ and K^+ were prepared with concentrations in parts per million (ppm).

Determination of acid extractable K^+

Potassium was extracted from soil sample using three extracting solutions: 1N hydrochloric acid (HCl); 1N nitric acid (HNO_3); and concentrated perchloric acid ($HClO_4$) which were used to extract the total form of potassium (Wood, De Turk 1941).

Nitric acid extractable K^+

The Nitric acid and K were performed according to Hanway and Heidel (1952). The standards of the K^+ was prepared in (ppm) for the nitric acid soluble potassium. The intensities of flame emission for potassium standards were recorded and plotted against their various concentrations in (ppm) the intensity of flame emission for each of the extracts was also recorded. The concentrations K^+ in the nitric acid extracts were determined from the graph of standards using their flame emission intensities Hanway and Heidel (1952). The differences between the value obtained and that of exchangeable K^+ is termed fixed K.

Hydrochloric acid extractable K^+

The hydrochloric acid extractable K^+ was performed according to Bouyoucous (1962)

Perchloric acid extractable potassium (Total K)

According to Jackson (1973) the total potassium in the studied soil was investigated

Statistical Analysis

Descriptive statistics were determined for each soil parameters using SPSS software. Correlation analysis procedure of SPSS was used to assess the relationship between the analyzed parameters.

Results and Discussion

The range values of exchangeable cations of Patigi surface soil is presented in Table 1. The Exchangeable Na^+ of the analyzed soils was very low to moderate. The values ranged from 0.00 – 0.27 cmol/kg of soil. Na^+ saturation percentage greater than one can cause soil quality problems and interfere with normal plant growth. Apart from being poisonous to roots, it can limit water movement and restricting root growth (Annon 2004). The exchangeable K^+ of the soils are very low with values of 0.11 – 0.30 cmol/kg. This is consistent with the report by Ajiboye and Ogunwale (2008) who observed the range of 0.11 - 0.20 cmol/kg in the clay fraction of the surface soils of Ejigba, Kogi State, Nigeria. In addition, Ndukwu et al. (2012) reported a mean value of 0.11 and 0.10 in Nkwoagu soils of Abia State, Nigeria, respectively. These values are lower than those obtained in the present study. The authors, however, observed higher value of 0.45 cmol/kg in Bendel soils of the State.

Unamba-Oparah, (1985) and Ano, Okeke (1987) have reported that soils having exchangeable K^+ values higher than 0.4 cmol/kg are regarded as better endowed with this form of K^+. The lower values recorded for exchangeable K^+ in this study might be due to depletion arising from continuous cropping activities as known for soils of this part of Nigeria. Reported values of exchangeable K varied widely across the different ecologies of the country. These values ranged between 0.04 and 0.34 cmol/kg for some Nigerian soils in the savanna region (Wild 1971); 0.03 to 0.33 cmol/kg for some Eastern Nigeria soils (Ekpete 1972) and 0.08 to 1.18 cmol/kg for Southern guinea savanna and rainforest agro-ecologies Udo and Ogunwale (1978).

According to Adepetu and Sobulo (1987), the availability of K in soils is a function of Exchangeable K^+ content of the soil. Thus, the exchangeable K is the amount of K which is available for plant use (Yagodin 1984). Calcium values in the surface soils ranged from 0.10 – 5.1cmol/kg of soil while that of Magnesium ranged from 0.1 – 2.9 cmol/kg of soil. The values for both Na and K are comparatively lower to those of Ca and Mg in the surface soils. The low K: Ca or K: Ca + Mg could hinder K uptake in these soils. Wild (1971) reported a leaching of K in New Zealand soil due to dislodgement of K by Ca owing to selective absorption process of Ca. Ekpete (1972) also recorded a reduced K uptake by plants in soils containing a high concentration of soluble Ca.

Table 1. *Range of exchangeable Cations in Patigi Surface Soils*

Ranking	Exch Na^+ (cmol/kg of soil)	N	Exch K^+ (cmol/kg of soil)	N	Excha Ca^{2+} (cmol/kg of soil)	N	Exch Mg^{2+} (cmol/kg of soil)	N
V low	0.00 – 0.06	9	0.11 – 0.20	25	0.10 – 1.90	4	0.1 – 0.9	3
Low	0.07 – 0.13	13	0.21 – 0.30	5	2.00 – 2.90	10	1.0 – 1.9	14
Moderate	0.14 – 0.20	7	0.31 – 0.40	-	3.00 – 3.90	4	2.0 – 2.9	13
High	0.21 – 0.27	1	0.41 – 0.50	-	4.00 -5.10	12	3.0 – 3.9	-

Exch= Exchangeable, N= Number of samples

The Extractable K^+ in 1N HCl and in 1N HNO_3 was higher than NH_4OAc exchangeable K^+ (Table 2). It could be that, more of this K^+ is contained in forms which are soluble in these acids than in NH_4OAc solution. Also, the HNO_3 extractable K^+ was observed to be higher than the HCl extractable K^+. The mobile K–reserve determined by 1N HNO_3extractant was higher in all the soils than the corresponding K-reserve assessed by 1N HCl extractant.

Table 2. *Range of Acid Extractable Potassium in Patigi Surface Soils*

Ranking	HCl Extract K^+ (cmol/kg of soil)	N	HNO_3 Extract K^+ (cmol/kg of soil)	N	$HCl0_4$ Extract K^+ (cmol/kg of soil)	N
V Low	1.5 – 2.0	5	1.5 – 2.5	5	3.1 – 5.0	14
Low	2.1 – 2.6	16	2.6 – 3.6	22	5.1 – 7.0	11
Moderate	2.7 – 3.2	7	3.7 – 4.7	1	7.1 – 9.0	2
High	3.3 – 3.8	2	4.8 – 5.8	2	9.1 -11.0	3

Extrac= Extractable, N= Number of samples

The total potassium (K) verified by concentrated perchloric acid ($HClO_4$) indicated higher values than other forms of K in the soils. The total K usually reflects the nature and degree of weathering of the parent materials.

The high value for total K in the studied soils may be as a result of the present of K bearing minerals like feldspars and mild weathering associated with it, as well as low rainfall regime of study areas. This assertion is supported by (Udo, Ogunwale 1978).

Figure 3. *Map of Patigi LGA showing the available K in the studied areas*

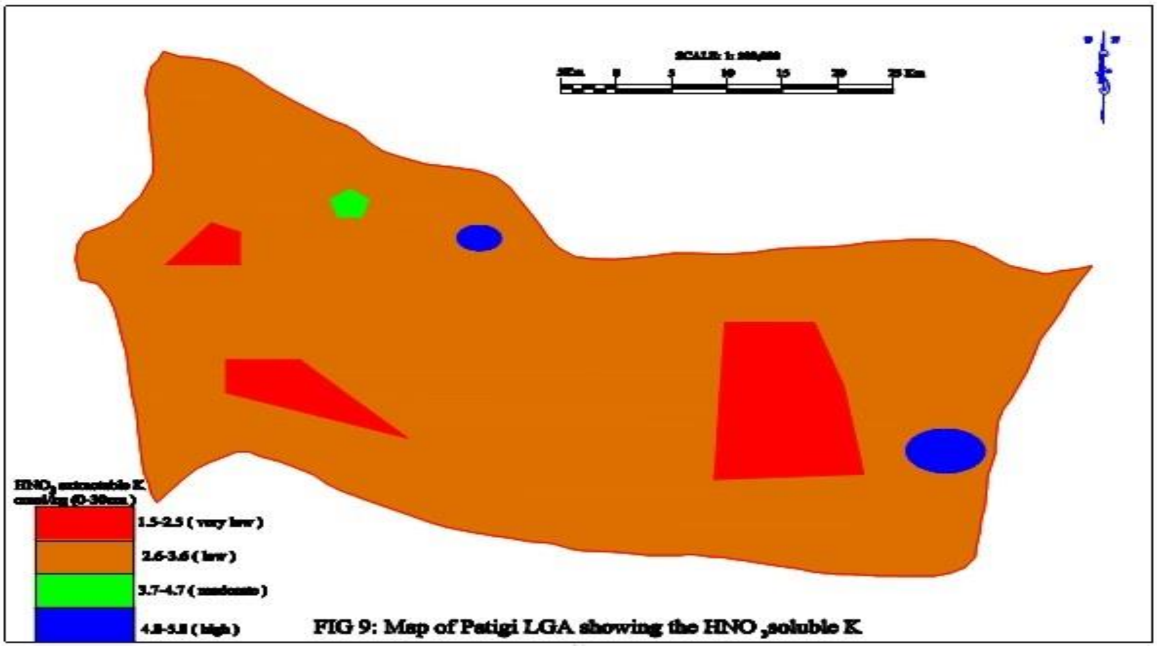

Figure 4. *Map of Patigi LGA showing the HNO_3 soluble K of the studied areas*

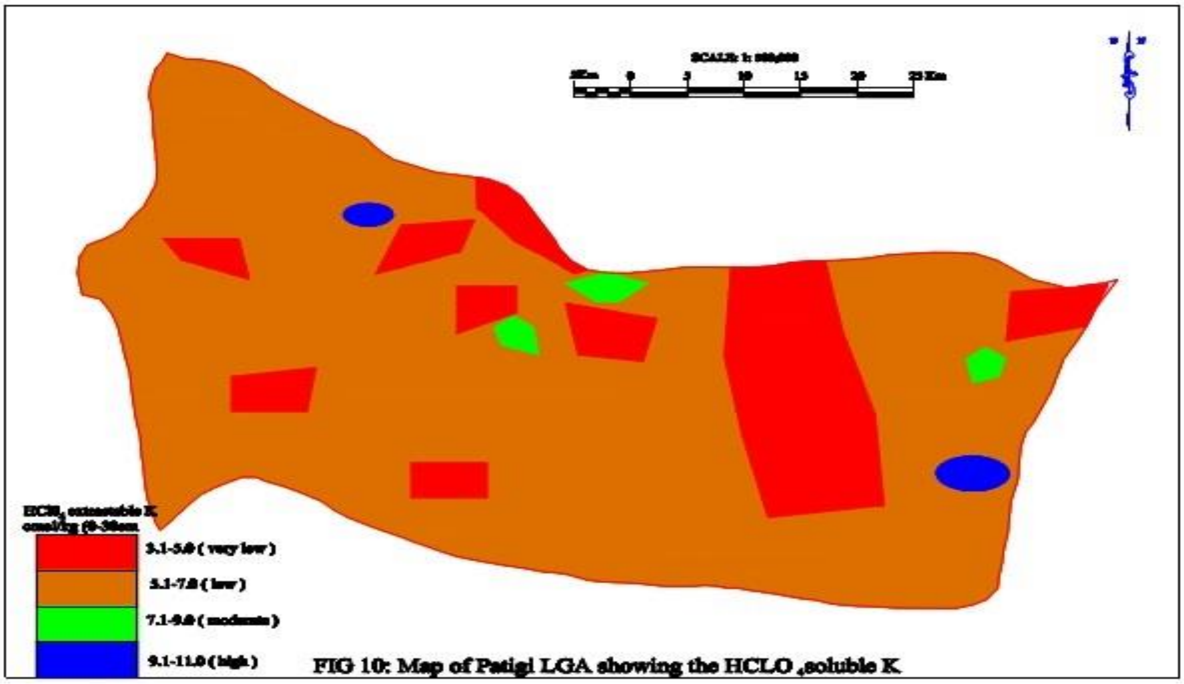

Fig 5: *Map of Patigi LGA showing the HCLO4 soluble K of the studied areas*

Table 3: *Correlation between Forms of Potassium, pH, Organic Matter and Exchangeable Bases*

	Exch Ca^{2+}	Exch Mg^{2+}	Ecxh Na^{+}	Avail K^{+}	HCL Ext K	HNO_3 Ext K	$HClO_4$ Ext K
Exch Ca	-	0.93**	0.06	-0.09	-0.08	-0.07	-0.02
Exch Mg		-	0.15	-0.06	-0.06	-0.03	0.01
Exch Na			-	0.15	0.11	0.16	0.17
Avail K				-	0.98**	0.93**	0.90**
HCL Ext K					-	0.95**	0.91**
HNO_3 Ext K						-	0.97**
$HCl0_4$ Ext K							-

** P<0.01, Exch= Exchangeable, Avail= Available, Ext= Extractable

Table 3 shows the correlation coefficients of the linear regression between soil K forms. Available K correlated positively and significantly (P< 0.01) with HCl Extractable K^{+} (r = 0.98); $HN0_3$ Extractable K^{+} (r=0.93) and the $HClO_4$ Extractable K^{+} (r=0.90) at 0.01 probability level. This is consistent with findings of Nabiollahy et al. (2006), Padol and Mahajan (2003), and Sharpley (1989). It is also agreement with the finding of Najafi Ghiri et al. (2010) who reported correlation value of r = 0.88, 0.96 and 0.83 between exchangeable K^{+} and $HN0_3$eExtractable K^{+}, for three different groups of Iranian soil, respectively. The findings in this study imply that the availability of K in soils is a function of Exchangeable K^+ content in the soil, thus, an increase in any one will lead to an increase in the other. Similar observation was made by Adepetu and Sobulo (1987), that the accessibility of K in soils is a function of Exchangeable K^+ content of the soil.

Conclusion

The surface soils in Patigi LGA are generally low in exchangeable K^+.
The values of the extractable K^+ increased in the order of NH4OAC <HCl< HNO3< HClO4. K forms correlated positively and significantly among each other, thus an increase in one form will lead to a corresponding increase in the other.

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