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Harsha BR
Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dharwad, UAS, Dharwad, Karnataka, India

Jagadeesh BR
Associate Professor, Department of soil Science and Agricultural Chemistry, College of Agriculture, Hanumanamatti, UAS, Dharwad, Karnataka, India

Correspondence
Harsha BR
Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dharwad, UAS, Dharwad, Karnataka, India

Surface and sub-surface soil potassium dynamics in a selected red soil type

Harsha BR and Jagadeesh BR

Abstract

The potassium dynamics in red soils of maize growing areas of Haveri district, Karnataka was studied in UAS, Dharwad during 2016-17. Potassium exists in soil in different forms such as water soluble, exchangeable, non-exchangeable, lattice K. The available potassium varied from 268.80 to 483.84 kg ha^{-1} in surface layer and sub-surface layer ranged from 215.04 to 376.32 kg ha^{-1}. The water soluble potassium varied from 1.66 to 4.69 mg kg^{-1} with a mean of 2.91 mg kg^{-1} in surface depth. The sub-surface water soluble K content varied from 1.31 to 3.39 mg kg^{-1} with a mean of 2.24 mg kg^{-1}. The water soluble potassium in selected red soils of maize growing areas of Haveri district varied from 1.66 to 4.69 mg kg^{-1} with a mean of 2.91 mg kg^{-1} in surface depth. The sub-surface water soluble K content varied from 1.31 to 3.39 mg kg^{-1} with a mean of 2.24 mg kg^{-1}. The exchangeable potassium content of red soils ranged from 44.80 to 78.40 mg kg^{-1} in surface layer. The sub-surface exchangeable potassium content of red soils varied from 30.60 to 67.20 mg kg^{-1}. The water soluble and exchangeable K was more in surface than in sub-surface. The non-exchangeable potassium ranged from 495.88 to 653.66 mg kg^{-1} in surface and 592.27 to 860.85 mg kg^{-1} in sub-surface layer. The lattice potassium of red soils ranged from 0.92 to 1.28 per cent in surface samples. The lattice potassium in sub-surface layer ranged from 0.98 to 1.42 per cent. The total potassium in surface depth of red soils varied from 0.97 to 1.35 per cent and that of sub-surface ranged from 1.05 to 1.50 per cent. The mean non-exchangeable, lattice and total K was noticed in sub-surface layer than in surface layer. The variation in potassium content of surface and sub-surface layers was mainly due to variation in clay content, weathering intensity and cultural practices.

Keywords: soil potassium dynamics, red soil, sub-surface layers

1. Introduction

Soil is a complex mixture of mineral particles, organic matter, water and air. The mineral particles come from the breakdown of rocks. As rocks break down into the particles of sand, silt and clay that make up soil, potassium and other elements are released and may become available to plants. It is important to assess the quantity of potassium in the soil solution and the readily available pool to ascertain whether or not to apply potassium fertilizer. Any increase or decrease in the amount of potassium in soil will show a direct effect on the plants growth. Information on the availability of potassium in soil of certain area may provide valuable information for agricultural needs. Therefore, it is important to understand the K status in the soil. The study area selected was Haveri district, Karnataka, India where intensive maize cultivation is undertaken. The twenty representative red soils were collected randomly using a GPS meter and studied in UAS, Dharwad, Karnataka during 2016-17. The soils varied appreciably in their physico-chemical properties both in surface and sub-surface layers. Levels of soil solution K are generally low, unless recent amendments of K have been made to the soil. Exchangeable K is the portion of the soil K that is electrostatically bound as an outer-sphere complex to the surfaces of clay minerals and humic substances. It is readily exchanged with other cations and also is readily available to plants. The exchangeable K content follow the order of clay per cent along with silt fraction: black soil followed by red, alluvial and laterite soils. Non-exchangeable K differs from mineral K in that it is not bonded within the crystal structures of soil mineral particles. It is held between adjacent tetrahedral layers of dioctahedral and trioctahedral micas, vermiculites and intergraded clay minerals such as chloritized vermiculite. Potassium get fixed because of binding forces between K and the clay surfaces are greater than the hydration forces between individual K^+ ions. This results in a partial collapse of the crystal structures and the K^+ ions are physically trapped to varying degrees, making K release slow and diffusion controlled process. Lattice K is generally assumed to be only slowly available to plants; however, the availability is dependent on the level of K in the other forms, and the degree of weathering of the feldspars and micas constituting the mineral K fraction.

Most of the total K in soils is in the mineral form, mainly as K-bearing primary minerals such as muscovite, biotite and feldspars. Common soil K-bearing minerals, in the order of availability of their K to plants are biotite, muscovite, orthoclase and microcline. Many tropical and subtropical soils are poor in mobile compounds of phosphorus, nitrogen and to a lesser extent potassium. The potassium content in tropical soils differ depending on the extent of weathering of their mineral part; the greater is the level of weathering, the lower is the content of potassium in the soil. Maize is grown in temperature between 18°C and 27°C during the day and around 14°C during the night. Maize is grown mostly in regions having annual rainfall between 60 and 110 cm. But it is also grown in areas having rainfall of about 40 cm. Maize grows on a wide range of soils, ranging from temperate podzols to the leached red soils of the tropics. But, the best suitable soil for maize is deep, rich soils of the sub-tropics, where there is abundant nitrogen and potassium. Karnataka accounts for 6 per cent area and 12 per cent of production share. The area under maize in Northern Karnataka is 52 per cent. The area under maize in Haveri district is 1,48,204 ha, with a production of 4,56,842 tonnes with an average productivity of 3,460 kg ha^{-1} (Anon., 2015) [1]. The adoption of hybrid maize varieties, exhaustive nature of the crop, new cultural practices and their interrelationships with nutrient supply have resulted in the application of ever increasing amounts of fertilizers in Karnataka. More fertilizers probably used for maize than for any other annual crop, and this in turn have given rise to new basic problems not considered previously. In Karnataka, the maize growing area is increasing rapidly, adoption of nutrient management practices in general and K nutrient management in particular is need of the hour. Hence, an immense study on K dynamics under maize cropping system of red soil type for both surface and sub-surface samples were studied.

2. Material and Methods

The surface and sub-surface samples of depth 0-20 cm and 20-50 cm, respectively were collected based on predominance of soil type (red) and dominance of cropped area under maize of Haveri district and studied during 2016-17 at UAS, Dharwad. The net cultivated area of the district is 17,488 ha (Anon., 2015) [1]. The annual rainfall of the region is 792.70 mm (Anon., 2015) [1]. The study location lies between the coordinates of 14˚ N to 75˚ E. The soil samples collected were air dried in shade, gently ground using wooden pestle and mortar and passed through 2 mm sieve. The sieved samples were preserved in polythene plastic covers for further analysis. Soil reaction was determined in 1:2.5 soil water suspension after stirring for 30 minutes using a pH meter (Jackson, 1973) [5]. It was determined in 1:2.5 soil: water suspension after obtaining supernatant as described by Jackson (1973) [5] using conductivity meter. Organic carbon was determined by Walkley and Black's wet oxidation method as described by Piper (1996) [12]. The per cent distribution of particles of different size *viz.*, sand, silt and clay was determined by mechanical analysis using Bouyoucos Hydrometer method (Jackson, 1973) [5]. Soils (50 g) were shaken with 100 ml of 5 per cent solution of sodium hexa meta phosphate. Later, per cent silt and clay was estimated by hydrometer and per cent sand was calculated by subtracting silt and clay from 100. The exchangeable calcium and magnesium were determined in the neutral normal ammonium acetate the aliquot of the extract was titrated against standard versenate solution and sodium and potassium were determined by flame photometry (Jackson, 1973) [5]. Available potassium was determined by extracting soil with neutral normal ammonium acetate and the contents of K in solution and was estimated by flame photometery (Jackson, 1973) [5].

Different forms of potassium was estimated by,

2.1. Water-soluble potassium

Water-soluble potassium was determined in 1:5 soil-water suspension after shaking for two hours and allowing to stand for an additional 16 hours (Black, 1965) [2]. The potassium in the extract was determined by flame photometer.

2.2. Exchangeable potassium

Exchangeable potassium was determined by extracting with *N N* NH_4OAc solution as outlined by Knudsen *et al*. (1982) [8]. Ten grams of soil sample was shaken with 25 ml of *N N* NH_4OAc solution for ten minutes and then centrifuged. The clear supernatant liquid was decanted into 100ml volumetric flask. Three more additional extractions were made in the same manner and the combined extract was diluted to volume with NH_4OAc. The K content in the extract was determined by flame photometer. The water soluble K was subtracted from NH_4OAc-K to get the exchangeable potassium content of the soil.

2.3. Non exchangeable potassium

The boiling 1*N* HNO_3 method as outlined by Knudsen *et al*. (1982) [8] was followed for determination of non-exchangeable K in soil.

Two and half gram of finely ground soil was boiled gently with 25 ml of 1*N* HNO_3 for 10 minutes. The content was filtered and the filtrate was collected in a 100 ml volumetric flask. The soil was then washed four times with 15 ml portions of 0.1 *N* HNO_3. After making up volume and mixing, the potassium content in the extract was determined using flame photometer. The quantity of K obtained with the NH_4OAc extract was subtracted to get the non-exchangeable potassium content in the soil.

2.4. Total potassium

Total potassium content was determined by digesting the samples with hydrofluoric acid in a closed vessel (Lim and Jackson, 1982) [11]. 200 mg of finely ground soil sample was transferred into 250 ml wide mouth polypropylene bottle. Two ml of aqua regia was added to disperse the samples. Later 10 ml hydrofluoric acid was added by means of plastic pipette and after capping the bottle the contents were shaken to dissolve the sample for a period of 8 hours. The white residue remaining after the treatment was dissolved in 100 ml of saturated H_3BO_3 solution. The contents were diluted and final volume was made to 250 ml and subsequently used for analysis of total potassium by flame photometer.

2.5. Lattice potassium

The lattice potassium was computed as difference between total potassium and the sum of water soluble, exchangeable and non-exchangeable K fractions.

3.Results and Discussion

The available potassium in red soils varied from 268.80 to 483.84 kg ha^{-1} in surface layer and sub-surface layer ranged from 215.04 to 376.32 kg ha^{-1}. The highest available potassium in both surface and sub-surface layer was recorded in Guttal soil and that of lowest in Aremallapur-4 soil, respectively. The mean available potassium in surface was 339.53 kg ha^{-1} and that of sub-surface layer was 281.44 kg ha^{-1}. The available potassium in red soils was medium to high in status. The variation in K status might be due to cultural practices, application of fertilizers, organic manures and other inputs. The surface available potassium in all most all soils was more compared to sub-surface. This may be due to the fact that application of water soluble potassium fertilizers and also high exchange sites offered for potassium at surface layer. Similar results were obtained by Yadav *et al.* (1991) [14], Upadhyay and Bhandari (1997) [13] and Jagadeesh (2003) [6]. Adequate level of available K in red soils of the study area may be due to the prevalence of K-rich clay minerals like illite and kaolinite. The water soluble potassium in selected red soils of maize growing areas of Haveri district varied from 1.66 to 4.69 mg kg^{-1} with a mean of 2.91 mg kg^{-1} in surface depth. The sub-surface water soluble K content varied from 1.31 to 3.39 mg kg^{-1} with a mean of 2.24 mg kg^{-1}. The highest water soluble K of surface and sub-surface layer was obtained in Guttal soil. The lowest water soluble K in surface depth was obtained in Medleri-5 soil. The water soluble K in sub-surface depth was recorded lowest in Hulgur-2 soil. The mean water soluble potassium was more in surface than that of sub-surface. Black soils recorded higher water soluble K at both surface and sub-surface depths. The reason for high water soluble K in black soil was mainly due to intensive weathering of K bearing minerals and also due external application water soluble K fertilizers under intensive farming system. The results were in corroboration with Lakaria *et al.* (2012) [10]. Further, the lower values in sub-surface depth may be due to K mining by exhaustive maize crop and also capillary movement of potassium ion from lower depth to upper portion. The results are on par with findings of Hebsur and Gali (2011) [4] and Lakaria *et al.* (2012) [10]. The exchangeable potassium content ranged from 44.80 to 78.40 mg kg^{-1} in surface layer. The sub-surface exchangeable potassium content varied from 30.60 to 67.20 mg kg^{-1}. The highest was obtained in soil of Aremallapur-5 for both surface and sub-surface depth. At both the depths the lowest value was recorded for Aremallapur-4 soil. The mean values of exchangeable K was 52.28 and 45.24 mg kg^{-1} in surface and sub-surface layers, respectively. The exchangeable potassium in surface layer was high because of high exchange sites offered for K fertilization and also addition of organic manures which might have enhanced the exchangeable K in solution phase. The lower values of exchangeable K in deeper depth of soil was due to fact that capacity of added nutrient remained in surface and paved for the crop uptake and also the less exchange sites availed by potassium ions at deeper depths of the soil (Divya *et al.*, 2016) [3]. The non-exchangeable potassium of red soils ranged from 495.88 to 653.66 mg kg^{-1} in surface and 592.27 to 860.85 mg kg^{-1} in sub-surface layer. The lowest was obtained in Medleri-5 soil and highest was obtained in Aremallapur-4 soil for surface depth. In sub-surface samples the highest was recorded in Aremallapur-4 soil and lowest in Aremallapur-2 soil. The surface samples were low with respect to non-exchangeable potassium compared to sub-surface depth. The non-exchangeable K was low in surface which might be due to release of potassium from reserve pool to compensate the loss of water soluble and exchangeable K by plant uptake. The increase in non-exchangeable potassium at sub-surface may be attributed to adsorption and fixation of K removed from surface through leaching. The similar findings were obtained by Kundu *et al*. (2014) [9] and Divya *et al*. (2016) [3]. The lattice potassium of soils ranged from 0.92 to 1.28 per cent in surface samples. The lattice potassium in sub-surface layer ranged from 0.98 to 1.42 per cent. The surface and sub-surface highest lattice potassium was obtained in Aremallapur-5 soil and lowest in Kenagapur-1 soil for both surface and sub-surface layers. The high values of red soil type in sub-surface indicate that these soils have been derived from potassium bearing minerals such as 2:1 type of clay minerals which favoured the lattice potassium content in soils. Based on degree of weathering the surface and sub-surface lattice K content might have been varied among the samples. The results corroborated with the findings of Divya *et al.* (2016) [3]. The total potassium in surface depth varied from 0.97 to 1.35 per cent and that of sub-surface ranged from 1.05 to 1.50 per cent. The surface total K was recorded highest in Aremallapur-5 soil and lowest in Savanur soil. The Aremallapur-5 and Kengapur-1 soils showed highest and lowest total K for sub-surface layers, respectively. The black soils total potassium ranged from 1.45 to 2.10 per cent in surface and 1.60 to 2.15 per cent in sub-surface layer. The lowest total potassium was recorded in soils of Bankapur-1 and highest in Rattihalli-6 soil for surface depth. The sub-surface depth highest total potassium was observed in soils of Jogihalli-4 and lowest in Bankapur-1 soil. The degree of weathering is important for total content of potassium in soils. Depending on clay mineralogy, lattice K content and organic matter content, the total K content might have been varied in surface and sub-surface layers. The results are in comparison with those of research findings of Hebsur and Gali (2011) [4], Jagmohan and Grewal (2014) [7] and Divya *et al*. (2016) [3].

Table 1: Details of surface and sub-surface soil samples collected from different places (red type) of Haveri district, Karnataka

Sl. No.	Taluk	Location	Latitude	Longitude
1	Shiggoan	Kengapur-1	15° 02' 23.0''	74° 59' 13.1''
2	Shiggoan	Kengapur-2	15° 02' 40.3''	75° 15' 37.3''
3	Shiggoan	Kengapur-3	15° 02' 29.7''	75° 15' 35.2''
4	Shiggoan	Hulgur-1	15° 01' 15.1''	75° 18' 42.0''
5	Shiggoan	Hulgur-2	15° 02' 25.5''	75° 15' 55.2''
6	Savanur	Savanur	14° 53' 55.2''	75° 20' 31.3''
7	Haveri	Guttal	14° 58' 12.2''	75° 24' 22.8''
8	Ranebennur	Aremallapur-1	14° 59' 18.0''	75° 60' 32.0''
9	Ranebennur	Aremallapur-2	14° 59' 20.0''	75° 60' 38.0''
10	Ranebennur	Aremallapur-3	14° 59' 38.1''	75° 60' 35.1''
11	Ranebennur	Aremallapur-4	14° 59' 38.2''	75° 60' 31.3''
12	Ranebennur	Aremallapur-5	14° 59' 17.0''	75° 60' 32.8''
13	Ranebennur	Medleri-1	14° 59' 19.9''	75° 60' 42.0''
14	Ranebennur	Medleri-2	14° 59' 57.2''	75° 60' 48.0''
15	Ranebennur	Medleri-3	14° 58' 59.1''	75° 60' 35.1''

16	Ranebennur	Medleri-4	14° 58' 37.1''	75° 60' 39.0''
17	Ranebennur	Medleri-5	14° 58' 36.2''	75° 59' 46.2''
18	Byadgi	Byadgi-1	14° 49' 54.0''	75° 46' 42.1''
19	Byadgi	Byadgi-2	14° 44' 15.3''	75° 46' 49.0''
20	Ranebennur	Hanumanamatti	14° 59' 11.8''	75° 39' 44.8''

Table 2: Chemical properties in selected surface and sub-surface red soils of Haveri district

Sample No.	$pH_{1:2.5}$		$EC_{1:2.5}$ (dS m^{-1})		OC (g kg^{-1})	
	Surface (0-20 cm)	Sub-surface (20-50 cm)	Surface (0-20 cm)	Sub-surface (20-50 cm)	Surface (0-20 cm)	Sub-surface (20-50 cm)
1	6.59	6.53	0.05	0.07	6.04	4.23
2	6.75	6.77	0.06	0.04	4.50	3.12
3	6.50	6.55	0.03	0.03	5.01	4.47
4	6.70	6.74	0.04	0.05	5.72	3.98
5	6.66	6.67	0.03	0.04	5.35	4.56
6	7.50	7.52	0.25	0.27	5.20	4.41
7	6.68	6.70	0.03	0.05	4.63	4.01
8	6.50	6.53	0.05	0.06	5.12	3.97
9	6.75	6.79	0.04	0.05	5.78	4.32
10	7.36	7.37	0.19	0.21	6.11	5.25
11	7.30	7.32	0.18	0.18	5.07	4.33
12	7.40	7.43	0.18	0.20	5.19	4.86
13	7.41	7.45	0.09	0.12	6.40	4.98
14	6.68	6.70	0.11	0.14	5.10	4.32
15	7.24	7.25	0.22	0.23	6.20	5.11
16	6.55	6.54	0.06	0.09	4.62	3.14
17	6.38	6.37	0.07	0.07	6.90	4.47
18	7.08	7.10	0.06	0.08	7.90	6.18
19	7.00	7.05	0.05	0.05	7.00	5.98
20	7.46	7.47	0.11	0.09	6.50	5.27
Range	6.38-7.50	6.37-7.52	0.03-0.25	0.03-0.27	4.50-7.90	3.12-6.18
Mean	6.92	6.94	0.09	0.11	5.72	4.54
S.D.	0.380	0.386	0.069	0.073	0.901	0.780

Table 3: Particle size distribution in selected surface and sub-surface red soils of Haveri district

Sample No.	Sand	Silt	Clay	Textural class	Sand	Silt	Clay	Textural class
	(%)				(%)			
	Surface (0-20 cm)				Sub-surface (20-50 cm)			
1	60.96	16.74	21.33	scl	53.36	23.11	26.40	scl
2	55.11	18.10	25.04	scl	50.85	20.65	28.34	scl
3	56.71	18.20	24.16	scl	43.29	21.25	37.48	cl
4	55.23	17.52	25.54	scl	50.42	25.74	29.55	scl
5	60.36	17.04	22.11	scl	48.34	20.24	30.45	scl
6	55.42	18.54	24.44	scl	54.22	21.47	25.11	scl
7	52.48	19.11	27.23	scl	48.53	20.10	29.54	scl
8	56.56	18.10	24.55	scl	49.75	25.04	29.87	scl
9	36.32	25.67	36.73	cl	30.31	25.00	37.67	cl
10	60.84	16.88	21.45	scl	52.62	20.15	28.48	scl
11	55.42	18.40	23.64	scl	48.59	22.31	30.42	scl
12	39.78	25.88	33.03	cl	35.62	28.96	34.57	cl
13	60.39	16.85	21.98	scl	56.05	23.41	24.45	scl
14	57.18	18.60	24.11	scl	44.72	23.89	35.54	cl
15	58.81	16.87	23.13	scl	51.97	20.98	28.20	scl
16	50.41	19.21	28.61	scl	41.43	24.86	34.23	cl
17	59.17	15.76	24.78	scl	51.33	21.85	31.25	scl
18	58.72	16.14	24.88	scl	51.95	21.92	28.12	scl
19	47.30	22.84	29.37	scl	41.11	24.97	35.02	cl
20	43.37	21.84	31.87	cl	43.62	26.14	32.82	cl
Range	36.32-60.96	15.76-25.88	21.33-36.73	Sandy clay loam to clay loam	30.31-56.05	20.10-28.96	24.45-37.67	Sandy clay loam to clay loam
Mean	54.02	18.91	25.24		47.40	23.10	30.87	
S.D.	7.13	2.91	4.15		6.55	2.42	3.86	
C.V.	13.19	15.38	16.44		13.81	14.47	12.50	

scl- Sandy clay loam
cl- Clay loam

Table 4: Exchangeable potassium percentage, potassium adsorption ratio, CEC and available K_2O in selected surface and sub-surface red soils of Haveri district

Sample No.	Exchangeable potassium percentage		Potassium adsorption ratio		CEC [cmol (p^+) kg^{-1}]		Available K_2O (kg ha^{-1})	
	Surface (0-20 cm)	Sub-surface (20-50 cm)	Surface (0-20 cm)	Sub-surface (20-50 cm)	Surface (0-20 cm)	Sub-surface (20-50 cm)	Surface (0-20 cm)	Sub-surface (20-50 cm)
1	14.33	10.69	2.23	1.73	15.21	19.26	328.56	268.82
2	12.92	8.12	1.91	0.74	19.34	25.98	376.32	256.20
3	8.75	7.43	1.08	0.90	23.65	26.48	274.30	228.80
4	10.95	9.33	1.94	1.69	19.36	20.45	321.12	272.40
5	12.47	8.01	0.89	0.63	16.92	19.37	271.80	225.24
6	9.88	6.38	1.51	0.81	21.86	24.89	312.96	237.42
7	14.49	9.63	2.98	1.90	24.15	25.94	483.84	376.32
8	12.14	7.48	0.89	1.01	16.88	20.31	302.16	258.60
9	8.32	7.23	2.12	1.94	26.32	27.78	322.56	298.20
10	15.41	11.95	2.67	1.41	16.22	19.32	430.08	321.56
11	9.27	7.20	1.10	1.03	22.76	24.97	268.80	215.04
12	9.24	8.50	1.65	1.21	27.05	28.92	430.08	366.38
13	11.93	7.49	1.85	0.84	18.43	21.22	341.26	295.04
14	10.74	8.14	1.37	1.03	20.29	24.68	302.54	261.35
15	13.07	10.41	1.38	0.87	17.21	19.23	323.51	271.80
16	8.17	7.15	1.92	1.15	24.83	27.54	371.32	298.13
17	10.89	6.58	0.95	0.71	18.36	22.78	269.80	235.04
18	17.35	14.96	2.07	1.54	17.86	20.05	374.82	342.96
19	9.20	7.43	2.21	1.51	23.14	27.16	376.22	320.76
20	8.15	5.97	1.36	1.09	24.66	26.09	308.56	278.81
Range	8.15-17.35	5.97-14.96	0.89-2.98	0.63-1.94	15.21-27.05	19.23-28.92	268.80-483.84	215.04-376.32
Mean	11.38	8.50	1.70	1.19	20.72	23.62	339.53	281.44
S.D.	2.63	2.15	0.58	0.40	3.63	3.38	59.08	46.01

Table 5: Exchangeable cations in selected surface and sub-surface red soils of Haveri district

Sample No.	Ca^{2+}		Mg^{2+}		K^+		Na^+		Sum of exchangeable cations	
	← [cmol (p^+) kg^{-1}] →									
	Surface (0-20 cm)	Sub-surface (20-50 cm)	Surface (0-20 cm)	Sub-surface (20-50 cm)	Surface (0-20 cm)	Sub-surface (20-50 cm)	Surface (0-20 cm)	Sub-surface (20-50 cm)	Surface (0-20 cm)	Sub-surface (20-50 cm)
1	8.00	11.60	3.60	3.62	2.18	2.06	0.41	0.47	14.19	17.75
2	11.20	16.80	4.00	6.00	2.50	2.11	0.31	0.53	18.01	25.44
3	15.60	19.20	2.80	3.20	2.07	1.97	0.36	0.59	20.83	24.96
4	11.20	11.60	4.00	4.00	2.12	1.91	0.61	0.69	17.93	18.20
5	10.40	12.80	2.40	3.60	2.11	1.55	0.45	0.72	15.36	18.67
6	10.80	15.60	6.40	5.60	2.16	1.59	0.48	0.61	19.84	23.40
7	11.20	13.20	7.20	7.60	3.50	2.50	0.69	0.77	22.59	24.07
8	9.60	13.00	3.20	4.40	2.05	1.52	0.39	0.52	15.24	19.44
9	16.00	16.80	5.20	6.00	2.19	2.01	0.46	0.65	23.85	25.46
10	8.00	10.40	3.60	4.80	2.50	2.31	0.54	0.70	14.64	18.21
11	12.00	12.80	5.20	9.20	2.11	1.80	0.49	0.61	19.80	24.41
12	13.60	15.20	7.60	8.80	2.51	2.46	0.43	0.54	24.13	27.00
13	8.40	12.00	5.20	5.20	2.20	1.59	0.47	0.58	16.27	19.37
14	13.20	15.60	2.80	5.60	2.18	2.01	0.52	0.71	18.70	23.92
15	8.40	10.80	4.00	4.80	2.25	2.00	0.57	0.62	15.22	18.22
16	14.00	15.20	6.00	7.60	2.03	1.97	0.47	0.54	22.50	25.31
17	10.00	12.80	4.00	6.40	2.00	1.50	0.34	0.41	16.34	21.11
18	9.60	11.60	3.20	3.60	3.10	3.00	0.61	0.72	16.51	18.92
19	15.20	16.80	2.80	6.00	2.13	2.02	0.49	0.67	20.62	25.49
20	14.00	16.80	6.00	6.02	2.01	1.56	0.37	0.52	22.38	24.88
Range	8.00-16.00	10.40-19.20	2.40-7.60	3.20-9.20	2.00-3.50	1.50-3.00	0.31-0.69	0.41-0.77	14.19-24.13	17.75-27.00
Mean	11.38	13.88	4.37	5.58	2.30	1.99	0.47	0.61	18.55	22.07
S.D.	2.57	2.47	1.54	1.71	0.38	0.38	0.09	0.09	3.23	3.24

Table 6: Forms and distribution of potassium in surface and sub-surface red soils of Haveri district

Sample No.	Water soluble K (mg kg^{-1})		Exchangeable K (mg kg^{-1})		Non-exchangeable K (mg kg^{-1})		Lattice K (%)		Total K (%)	
	Surface (0-20 cm)	Sub-surface (20-50 cm)	Surface (0-20 cm)	Sub-surface (20-50 cm)	Surface (0-20 cm)	Sub-surface (20-50 cm)	Surface (0-20 cm)	Sub-surface (20-50 cm)	Surface (0-20 cm)	Sub-surface (20-50 cm)
1	3.24	2.82	45.81	35.60	540.96	690.31	0.92	0.98	0.98	1.05
2	3.37	1.42	56.24	48.12	586.04	726.27	0.94	1.07	1.00	1.15
3	2.02	1.83	45.86	36.61	608.58	690.29	1.04	1.15	1.10	1.23
4	3.16	3.02	44.87	34.23	540.96	667.94	0.97	1.08	1.03	1.15
5	1.71	1.31	48.70	41.60	586.04	756.44	1.04	1.12	1.10	1.20
6	2.89	1.70	45.84	40.24	586.04	780.95	0.93	1.02	0.97	1.10
7	4.69	3.39	68.40	56.09	540.96	622.17	1.25	1.38	1.30	1.45
8	1.90	2.30	54.20	38.80	495.88	640.55	0.95	1.03	1.00	1.10
9	3.19	3.16	44.82	39.14	518.42	592.27	1.15	1.26	1.20	1.32
10	4.58	2.63	56.20	50.89	631.12	792.91	1.18	1.29	1.25	1.37
11	2.00	2.06	44.80	30.60	653.66	860.85	1.25	1.38	1.33	1.47
12	2.60	2.17	78.40	67.20	653.66	777.06	1.28	1.42	1.35	1.50
13	2.96	1.57	52.11	56.11	631.12	765.21	1.06	1.14	1.13	1.23
14	2.17	1.81	51.27	44.98	540.96	658.40	1.02	1.10	1.08	1.17
15	2.32	1.63	54.81	49.62	518.42	630.40	1.09	1.20	1.15	1.27
16	3.66	2.38	51.80	47.81	631.12	843.32	1.21	1.29	1.28	1.37
17	1.66	1.44	48.80	42.60	495.88	637.61	1.15	1.26	1.20	1.33
18	3.36	2.73	56.00	55.14	608.58	741.48	1.24	1.34	1.30	1.42
19	4.02	3.06	49.01	45.89	631.12	821.02	1.21	1.33	1.28	1.42
20	2.61	2.32	47.82	43.63	631.12	776.94	1.18	1.29	1.25	1.38
Range	1.66-4.69	1.31-3.39	44.80-78.40	30.60-67.20	495.88-653.66	592.27-860.85	0.92-1.28	0.98-1.42	0.97-1.35	1.05-1.50
Mean	2.91	2.24	52.28	45.24	581.53	723.62	1.11	1.20	1.16	1.28
S.D.	0.89	0.64	8.41	8.92	53.03	79.36	1.18	1.35	1.26	1.38

Conclusion

The result of the present investigation suggests that maximum K content of selected red soils is in the non-exchangeable form, mostly fixed up within the clay lattice rendering very small amount of available to plant. Knowledge of different forms of potassium in soil together with their distribution has greater relevance in assessing the long-term K supplying power of soil to crops and is important in formulating a sound fertilizer program for a given set of soil and crop. A future study on clay mineralogical make-up of the soils may help calibrating the reserve pool of K and the extent of its mining. This may help the planners to formulate an effective K fertilizer program for the soils of the region.

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