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Shivaprasad Patil
Department of Soil Science and Agricultural Chemistry, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

Jagadeesh BR
Department of Soil Science and Agricultural Chemistry, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

Patil PL
Department of Soil Science and Agricultural Chemistry, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

Correspondence
Shivaprasad Patil
Department of Soil Science and Agricultural Chemistry, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

Forms and distribution of potassium in selected black soil series of Kavalur sub-watershed soils of Koppal district, Karnataka

Shivaprasad Patil, Jagadeesh BR and Patil PL

Abstract
Potassium in soil exists in four different forms such as, water soluble, exchangeable, non-exchangeable and lattice potassium were studied in the surface and sub surface samples of Kavalur sub-watershed of Koppal district, Karnataka. The available potassium in black soil varied from 317.00 to 508.00 kg ha^{-1} in surface and 288.00 to 430.00 kg ha^{-1}in sub surface soil. The higher value of available potassium indicated that these soils were added with sufficient quantities of potash fertilizers. The water soluble K of black soils ranged from 2.08 to 9.72 mg kg^{-1} in surface and 1.54 to 5.68 mg kg^{-1} in sub surface soil. The reason for higher 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. The higher exchangeable potassium at surface zone was mainly due to the fact that these soils had good amount of organic matter content which might have retained more K ions at exchange sites and also potassium retained through external source. The non-exchangeable potassium of black soils in surface samples varied from 451.37 to 914.37 mg kg^{-1}and 499.07 to 955.14 mg kg^{-1} in sub surface. The lattice potassium in black soil ranged from 13,300 to 27,400 mg kg^{-1}in surface and 14,600 to 29,800 mg kg^{-1} in sub surface. The type and nature of parent material present and degree of weathering are important for the rich lattice potassium content in the soils. Total potassium ranged from 14,100 to 28,600 mg kg^{-1} in surface and 15,500 to 31,000 mg kg^{-1}in sub surface soils. The higher values of total K obtained were mainly because of higher lattice K concentration. The degree of weathering, type and amount of clay and K fertilizer application influences different forms of potassium.

Keywords: Forms of potassium, black soil, intensive weathering, watershed.

1. Introduction
Potassium is present in very large amounts in most of the soils in the world. But its availability to crops is conditioned by several factors such as, type of primary and secondary minerals present in the soil, climatic conditions of the region and intensity of weathering of minerals, thickness of vegetation in the region, organic matter content of the soil and application of potassic fertilizers. The soils vary greatly with respect of type and amount of various clay which are formed by weathering of primary minerals and their mechanical composition. The reaction of these clay minerals with other solids in soil and soil solution may vary due to varying influences of the climatic components and farm management practices from time to time. Accordingly, the behavior of potassium contained in different forms in soil particularly the fraction held by the clay minerals may change considerably depending upon the occasion.
Potassium is the major nutrient and also a most abundant element in soil but the K content of the soil varies from place to place based on physico-chemical properties of soil. Potassium exist in soil in different forms *viz.,* water soluble K, exchangeable K, non-exchangeable K, mineral K, lattice K and total K and these forms are heterogeneously distributed in soils. Its amount in soil depends on the parent material, degree of weathering, K gains through manures and fertilizers and losses due to crop removal, erosion and leaching. Usually the amounts of non-exchangeable K and total K present in the soil are high compared to water soluble K and exchangeable K. The dynamics of potassium in soil depends on the magnitude of equilibrium among various forms and mainly governed by the physico-chemical properties of soil. The bulk of soil potassium (about 98% of total K) usually exists in unavailable form in primary (micas and feldspars) and secondary (illite group) clay minerals. The available K and exchangeable K in general are readily available to plants.

Koppal district with a geographical area of 5559 km^2 is located in the northern part of Karnataka state. Koppal district includes four taluks *viz.,* Gangavati, Koppal, Kushtagi and Yalburga. The area falls in the Tungabhadra sub-basin of the Krishna basin. It comprises of both red and black soils differing in morphological, physical and chemical characteristics. The geology of the area is comprised of biotitic schists, amphibites and hornblende. Black cotton soil is predominant in basalt and gneissic terrain, while red soil in granites and grey granite area. The district has on an average about 69 per cent net sown area while the forest occupies only about 5.3 per cent. The total land area not available for cultivation is about 10 per cent out of that non-agriculture land is 7 per cent and the remaining is barren (Anon., 2011) [3].

The Kavalur sub-watershed located in Koppal taluk of Koppal district has diversified crop, climate and soils. Hence, the study on heterogeneity of soils of Kavalur with respect to forms and distribution of K were studied to understand the current need of fertilizer management in general and potassium management.

2. Material and Methods

The surface samples were collected based on soil heterogeneity and slope in sub-watershed of Koppal district and studied during 2017-18 at UAS, Dharwad. The annual rainfall of the region is 572.37 mm (Anon., 2016) [4]. The Kavalur sub-watershed is located between 15^0 15′ 35.2″ and 15^0 18′ 30.1″ N latitude and 75^0 54′ 56.7″ and 75^0 57′ 28.9″ E longitude. The collected soil samples 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. Available potassium was determined by extracting soil with neutral normal ammonium acetate and the contents of K in solution and was estimated by flame photometer (Jackson, 1973) [9].

Different forms of potassium was estimated by,

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) [5]. The potassium in the extract was determined by flame photometer.

Exchangeable potassium

Exchangeable potassium was determined by extracting with N *N* NH_4OAc solution as outlined by Knudsen *et al.* (1982) [12]. 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 100 ml 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.

Non-exchangeable potassium

The boiling 1*N* HNO_3 method as outlined by Knudsen *et al.* (1982) [12] 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.

Total potassium

Total potassium content was determined by digesting the samples with hydrofluoric acid in a closed vessel (Lim and Jackson, 1982) [14]. 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.

Lattice potassium

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

Table 1: Details of soil samples collected from black soil types of Kavalur sub- watershed of Koppal district

Sl. No.	Series name	Series full name	Soil profile	Depth (cm)	Latitude (N)	Longitude (E)
1	MTL	Muttal	Kav-4/R_9	0-16 and 16-49	15° 15′ 39.8″	75° 57′ 21.3″
2	DRL	Dombarahalli	Kav-4/T_1/P_1	0-24 and 24-51	15° 15′ 57.8″	75° 57′ 10.7″
3	BGP	Budagumpa	Kav-4/T_1/P_3	0-35 and 35-90	15° 15′ 59.5″	75° 57′ 28.9″
4	TSD	Thimmasandra	Kav-1/T_2/P_3	0-22 and 22-54	15° 16′ 58.6″	75° 56′ 19.0″
5	KAV	Kavalur	Kav-2/R_9	0-26 and 26-64	15° 18′ 30.1″	75°55′ 44.9″
6	MLR	Murlapur	Kav-1/R_1	0-19 and 19-39	15° 15′ 59.5″	75° 57′ 28.9″
7	GRH	Gatareddihal	Kav-3/R_{11}	0-20 and 20-46	15° 17′ 14″	75° 55′ 47.8″
8	RNK	Revanki	Kav-3/R_2	0-11 and 11-32	15° 16′ 18.1″	75° 56′ 44.5″
9	AWD	Alawandi	Kav-2/T_1/P_2	0-30 and 30-66	15° 18′ 20.3″	75° 55′ 07.7″
10	BDR	Bardur	Kav-1/R_9	0-20 and 20-82	15° 17′ 27.0″	75° 55′ 17.8″
11	DRL-1	Degraded land	Kav-1/R_5	0-18 and 18-32	15° 17′ 6.5″	75° 56′ 44.5″
12	DRL-4	Degraded land	Kav-1/R_1	0-20 and 20-46	15° 16′ 43″	75° 55′ 56.6″

Table 2: Available potassium status in black soil series of Kavalur sub-watershed of Koppal district

Sl. No.	Black soil series	Available K_2O (kg ha^{-1})	
		Surface	Sub surface
1	AWD	508.00	430.00
2	BDR	491.00	288.00
3	BGP	350.00	342.00
4	DRL	317.00	304.00
5	DRL-1	328.00	307.00
6	DRL-4	418.00	397.00
7	GRH	453.00	395.00
8	KAV	396.00	338.00
9	MLR	482.00	367.00
10	MTL	414.00	404.00
11	RNK	471.00	425.00
12	TSD	390.00	351.00
Range		**317.00 – 508.00**	**288.00 – 430.00**
Mean		**418.16**	**362.33**
S.D.		**64.50**	**48.29**

Table 3: Forms and distribution of potassium in black soil series of Kavalur sub-watershed of Koppal district

Sl. No.	Black soil series	Water soluble K		Exchangeable K		Non-exchangeable K		Lattice K		Total K	
		(mg kg^{-1})									
		Surface	Sub surface	Surface	Sub surface	Surface	Sub surface	Surface	Sub surface	Surface	Sub surface
1	AWD	9.72	5.68	222.66	189.62	914.37	955.14	27918.01	30240.20	28600	31000
2	BDR	2.24	1.68	218.47	127.95	451.37	499.07	17669.34	18330.60	17900	18700
3	BGP	2.98	2.90	155.35	151.50	619.14	724.42	19739.19	23130.00	20200	23700
4	DRL	3.68	2.52	140.29	134.76	534.02	537.15	16709.95	17900.10	17100	18300
5	DRL-1	2.08	1.54	145.53	136.66	643.78	686.35	13603.83	14951.90	14100	15500
6	DRL-4	6.40	2.12	184.04	176.47	677.60	780.85	16612.84	17997.70	17100	18600
7	GRH	4.50	2.26	200.28	175.55	722.40	779.97	19682.38	21197.80	20200	21800
8	KAV	3.84	3.22	175.16	149.77	602.34	676.26	19276.66	21376.70	19700	21900
9	MLR	9.42	4.02	211.38	162.44	776.38	829.02	21744.42	22337.40	22300	23000
10	MTL	6.84	4.24	181.91	178.68	540.29	570.08	17748.46	18212.80	18100	18600
11	RNK	5.64	3.22	207.75	188.33	816.70	870.02	20496.69	20821.50	21100	21500
12	TSD	3.56	2.08	172.65	155.91	743.23	745.02	22932.98	24813.00	23500	25400
Range		**2.08-9.72**	**1.54-5.68**	**140.29-222.66**	**127.95-189.62**	**451.37-914.37**	**499.07-955.14**	**13603.83-27918.01**	**14951.90-30240.20**	**14100-28600**	**15500 - 31000**
Mean		**5.075**	**2.95**	**184.62**	**160.63**	**670.13**	**721.11**	**19511.22**	**20942.50**	**19991.67**	**21500.00**
S.D.		**2.57**	**1.21**	**28.09**	**21.20**	**132.00**	**136.64**	**3644.69**	**4005.85**	**3723.74**	**4086.56**

4. Results and Discussion

The available potassium in black soil series varied from 317.00 to 508.00 kg ha^{-1} in surface soil and 288.00 to 430.00 kg ha^{-1} in sub surface soil. The highest available potassium for both surface and sub surface soils was obtained in AWD soil series and lowest value in surface soil was 317.00 kg ha^{-1} in DRL soil series and in sub surface was 288.00 kg ha^{-1} in BDR soil series. The mean values of available potassium were 418.16 and 362.33 kg ha^{-1} in surface and sub surface soils respectively. The high value of potassium in surface soils indicated that these soils were added with sufficient quantities of potash fertilizers. The higher values of potassium in sub surface soil were due to dominance of potassium rich micaceous and feldspar minerals as observed by Anjali, (2017) [2]. Similar results were also reported by Patil *et al.* (2017) [16] in soils of Mevundi sub-watershed and Patil *et al.* (2018) [17] in soils of Dudihal sub-watershed.

The water soluble K of black soil series ranged from 2.08 to 9.72 mg kg^{-1} in surface soil with a mean of 5.07 mg kg^{-1}. The water soluble potassium in sub surface soil varied from 1.54 to 5.68 mg kg^{-1} with a mean of 2.95 mg kg^{-1}. The water soluble potassium in surface layer was lowest in DRL-1 (2.08 mg kg^{-1}) soil series and highest in AWD (9.72 mg kg^{-1}) soil series. The highest sub surface water soluble K was recorded in AWD (5.68 mg kg^{-1}) soil series and lowest in DRL-1 (1.54 mg kg^{-1}) soil series. The water soluble potassium was high in surface soil of black soil series like AWD, GRH compared to sub surface layers. The reason could be an upward translocation of K by capillary rise (Anil *et al.*, 2009) [1] further, due to vegetation, release of liable K from organic residues and addition of fertilizer and farm yard manure (Ranganathan and Satyanarayana 1980) [18]. Similar observations were made by Divya *et al.* (2016) [7].

The black soil series exchangeable potassium varied from 140.29 to 222.66 mg kg^{-1} in surface, 127.95 to 189.62 mg kg^{-1} in sub surface soils. In surface depth, exchangeable potassium was recorded highest in AWD (222.66 mg kg^{-1}) soil series and lowest in DRL (140.29 mg kg^{-1}) soil series. The highest exchangeable potassium in sub surface soil was recorded in AWD (189.62 mg kg^{-1}) soil series and lowest in BDR (127.95 mg kg^{-1}) soil series. The mean content of exchangeable K was 184.62 and 160.63 mg kg^{-1} in surface and sub surface soils, respectively. Black soil series were high with respect to exchangeable potassium in surface soil as compared to sub surface soil due to relatively higher organic carbon content and cation exchange capacity of soils in the surface soil (Singh *et al.,* 1983) [19]. AWD, BDR, DRL and all most all soil series showed the decrease in content of exchangeable K at sub surface zone. It was mainly due to capillary action of K^+ ions from sub surface to surface sites and decreased exchange sites and increased compactness at lower depth (Divya *et al.,* 2016) [7]. The higher exchangeable potassium in surface layer than that of subsurface layers due to higher crop residues and aggregation of humus content. Potassic fertilizer application in the surface layer and variation in clay content. Similar results were reported by Kaptan *et al.,* 2001, Hebsur and Gali (2011) [11, 8], (Jagadeesh, 2003) [10].

The non-exchangeable potassium of black soil series in surface soils varied from 451.37 to 914.37 mg kg^{-1} and 499.07 to 955.14 mg kg^{-1} in sub surface soils. The surface non-exchangeable potassium recorded lowest in BDR (451.37 mg kg^{-1}) soil series and highest in AWD (914.37 mg kg^{-1}) soil series. The sub surface non-exchangeable potassium recorded lowest in BDR (499.07 mg kg^{-1}) soil series and highest in AWD (955.14 mg kg^{-1}) soil series. The average non-exchangeable potassium of surface soil of black soil series recorded 670.13 mg kg^{-1} and sub surface soil was 721.11 mg kg^{-1}. AWD, MLR, GRH and other soil series showed the variation in the non-exchangeable K content in both depths was due to difference in the clay contents of the soils (Singh *et al.,* 1985) [20]. The highest content of non-exchangeable K in sub surface soil was related to clay content which could fix the K in soils, due to presence of illicit and other 2:1 types clay minerals the low reserve of this form in the surface soil could be due to its release in the exchangeable form as a result of its depletion by crop uptake and leaching loss. The similar findings were obtained by Kundu *et al.* (2014) [13] and Divya *et al.* (2016) [7]. Non-exchangeable K was higher reserved in the sub surface than surface soil possibly because of more clay and silt contents.

The lattice potassium of black soil series ranged from 13603.83-27918.01 mg kg^{-1}in surface soils. The lattice potassium in sub surface soils ranged from 14951.90-30240.20 mg kg^{-1}. The highest was recorded in AWD (27918.01 mg kg^{-1}) soil series and lowest in DRL-1 (13603 mg kg^{-1}) soil series for surface depth. The lowest lattice K in sub surface depths was recorded in DRL-1(14951.90 mg kg^{-1}) soil series and highest in AWD (30240.20 mg kg^{-1}) soil series. The mean lattice potassium was highest (20942.50 mg kg^{-1}) in black soils. Sub surface soils had more mean lattice potassium compared to surface soils (19511.22 mg kg^{-1}) of black soil series. The contents of lattice K was relatively higher at sub surface soils. This was mainly due to the difference in the intensity of weathering of soils in the two depths, the intensity being more in upper layer compared to the lower layers of soils. The variation in lattice potassium content in soil is attributed to nature and amount of clay *viz,* 2:1 type and extent of weathering of these minerals (Chahal *et al.,* 1976) [6]. Fairly high content of lattice K indicates that these soils have been developed from mica-rich parent material and much of potassium is present in the mica-lattice similar results were also reported by Kundu *et al.,* 2014 [13].

In case of black soil series total potassium ranged from 14,100 to 28,600 mg kg^{-1} in surface and 15,500 to 31,000 mg kg^{-1} in sub surface soils. The lowest total potassium was recorded in soils of DRL-1(14,100 mg kg^{-1}) soil series and highest in AWD (28,600 mg kg^{-1}) soil series for surface depth. The sub surface depth highest total potassium was observed in AWD (31,000 mg kg^{-1}) soil series and lowest in DRL-1 (15,500 mg kg^{-1}) soil series. The mean total potassium of black soils was 19,991.67 mg kg^{-1} and 21,500.00 mg kg^{-1} in surface and sub surface soils, respectively. AWD, TSD and other soil series shows higher total K content in sub surface than surface soils. The amount of total K which depended largely upon the clay content of soils (Mehrotra *et al.,* 1973) [15] and type of clay. Higher proportion of 2:1 clay minerals like vermiculite, smectite presence resulted in more total k in sub surface than surface soil as observation made by Anjali, 2017 [2].

5. Conclusion

The result of the present investigation on forms and distribution of potassium in Kavalur sub-watershed soils of Koppal district suggested that maximum K content of the soils was non-exchangeable form which was mostly fixed up within the clay lattice rendering very small amount of available K 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 series and crops. This may help the planners to formulate an effective potassium fertilizer program in general for a zone, particularly for a soil type.

6. References

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