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

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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 red soil varied from 221.00 to 389.00 kg ha^{-1} in surface and 194.00 to 317.00 kg ha^{-1}in sub surface soil. The available potassium in red soil series was medium to high in status. BPR, MRD soil series shows higer potassium than KSP, GHT soil series. The variation in K status in red soil series might be due to cultural practices, application of fertilizers, organic manures and other inputs. The surface available potassium in soils was more compared to sub-surface. This may be due to the fact that in red soil series the kaolinite is dominant among secondary clay minerals followed by the smectite in the surface soils. The water soluble K of red soils ranged from 1.68 to 4.08 mg kg^{-1} in surface and 1.30 to 2.88 mg kg^{-1} in sub surface soil. Higher amount of sand and organic matter present in surface soil contributed for high water-soluble K than sub-surface soil. The exchangeable potassium in surface soil was high because of K fertilization and application of manures enriched the exchangeable sites of clay-humus complex there by increased the exchangeable K. The non-exchangeable potassium of red soils in surface samples varied from 356.77 to 764.96 mg $kg^{-1}$and 430.98 to 853.89 mg kg^{-1} in sub surface. The lattice potassium in red soil ranged from 14,675.06 to 22010.02 mg kg^{-1}in surface and 16281.07 to 22789.11 mg kg^{-1} in sub surface. The high values of 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. Total potassium ranged from 15,000 to 22,600 mg kg^{-1} in surface and 16,700 to 23,500 mg kg^{-1} in sub surface soils. Variation in the depth wise distribution of total potassium depends upon the relative effect of factors such as, soil texture, intensity of weathering of surface soils, organic carbon content and release of soluble potassium from organic residues, application of potassic fertilizers and leaching of potassium to lower horizons.

Keywords: forms of potassium, red soil, intensive weathering, watershed

Introduction
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.
The nature of the different forms of potassium equilibrium is variable and depends upon the soil type and nature of the clay minerals. The readily available K constitutes only 1 to 2 per cent of total K and exists in soil in two forms, *viz.*, solution K and exchangeable K adsorbed on soil colloidal surface (Brady and Weil, 2002) [4]. These forms remain in dynamic equilibrium with one another. The readily available K or water soluble K has been reported to be a dominant fraction in the initial stage while, exchangeable K and non-exchangeable K contribute more in the later stages of crop growth.

According to increasing order of plant availability, soil K exists in four forms *i.e*. mineral K (5000-25000 mg kg^{-1}), non-exchangeable K (50-750 mg kg^{-1}), exchangeable K (40-600 mg kg^{-1}) and solution K (1-10 mg kg^{-1}). K cycling or transformations among the K forms in soils are dynamic. Soils that are rich in vermiculite and micas can have large amounts of non-exchangeable K, whereas, soils containing kaolinite, quartz and other siliceous minerals contain less available and exchangeable K (Martin and Sparks, 1985) [14].

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 of 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) [1].

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, its release and fixation characters were initiated to understand the current need of fertilizer management in general and potassium management in particular

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) [12]. 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) [10].

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). 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). 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) 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) [13]. 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 red soil types of Kavalur sub- watershed of Koppal district

Sl. No.	Series name	Soil profile	Depth (cm)	Latitude (N)	Longitude (E)
1	MRD	Kav-1/T_1/P_3	0-24 and 24-74	15° 17′ 4.8″	75° 56′ 02.5″
2	HLK	Kav-1/R_{12}	0-16 and 16-49	15° 17′ 26.5″	75° 55′ 58.1″
3	KKR	Kav-1/R_6	0-12 and 12 -41	15° 17′ 4.8″	75° 56′ 14.3″
4	GHT	Kav-1/R_{11}	0-25 and 25-57	15° 17′ 14″	75° 55′ 47.8″
5	BPR	Kav-1/T_1/P_2	0-35 and 35-58	15° 16′ 56″	75° 55′ 51″
6	TGR	Kav-1/R_2	0-11 and 11-32	15° 16′ 56.8″	75° 56′ 34.8″
7	KSP	Kav-3/R_8	0-20 and 20-56	15° 16′ 45.5″	75° 57′ 3.4″
8	MNL	Kav-3/R_6	0-12 and 12 -41	15° 16′ 45.3″	75° 56′ 40.9″

Table 2: Chemical properties in red soil series of Kavalur sub-watershed of Koppal district

Sl. No.	Red soil series	pH (1:2.5)		EC (dS m^{-1})		OC (g kg^{-1})	
		Surface soils	Sub-surface soils	Surface soils	Sub-surface soils	Surface soils	Sub-surface soils
1	BPR	7.68	7.14	0.14	0.18	4.64	4.01
2	GHT	6.60	7.08	0.12	0.16	3.86	3.21
3	HLK	7.04	7.38	0.22	0.25	4.32	3.89
4	KKR	7.42	7.51	0.28	0.31	4.08	3.23
5	KSP	6.66	6.93	0.21	0.25	4.24	3.54
6	MNL	7.92	7.86	0.13	0.14	5.06	4.25
7	MRD	7.94	8.06	0.19	0.23	5.07	4.28
8	TGR	8.05	8.06	0.15	0.19	5.16	4.29
Range		6.60 - 8.05	6.93 - 8.06	0.12 - 0.28	0.14 -0.31	3.86-5.16	3.21-4.29
Mean		7.41	7.50	0.18	0.21	4.49	3.83
S.D.		0.58	0.44	0.05	0.05	0.50	0.45

Table 3: Particle size distribution in red soil series of Kavalur sub-watershed of Koppal district

Sl. No.	Red soil Series	Sand	Silt	Clay	Textural class	Sand	Silt	Clay	Textural class
		Surface soils (%)				Sub-surface soils (%)			
1	BPR	57.10	14.30	28.60	Scl	54.60	12.40	33.00	Scl
2	GHT	56.66	18.79	24.55	Scl	52.91	20.22	26.87	Scl
3	HLK	42.45	21.69	35.86	Cl	40.67	20.44	38.89	Cl
4	KKR	36.32	25.67	36.73	Cl	30.31	25.00	37.67	Cl
5	KSP	42.45	21.69	35.86	Cl	40.67	20.44	38.89	Cl
6	MNL	41.96	23.37	34.67	Cl	39.74	22.60	37.66	Cl
7	MRD	41.97	23.37	34.66	Cl	39.78	22.34	37.88	Cl
8	TGR	56.71	18.25	25.04	Scl	50.85	20.65	28.50	Scl
Range		36.32 -57.10	14.30 - 25.67	24.55 -36.73	Sandy clay loam to clay loam	30.31 - 54.60	12.40 -25.00	26.87 -38.89	Sandy clay loam to clay loam
Mean		46.95	20.89	31.99		43.69	20.51	34.92	
S.D.		8.41	3.61	5.09		8.31	3.65	4.85	

Scl: Sandy clay loam, Cl: Clay loam,

Table 4: Available potassium status in red and soil series of Kavalur sub-watershed of Koppal district

Sl. No.	Red soil series	Available K_2O (kg ha^{-1})	
		Surface soils	Sub-surface soils
1	BPR	389.00	317.00
2	GHT	265.00	217.00
3	HLK	252.00	239.00
4	KKR	308.00	232.00
5	KSP	221.00	194.00
6	MNL	328.00	299.00
7	MRD	335.00	254.00
8	TGR	309.00	253.00
Range		221.00-389.00	194.00-317.00
Mean		300.87	250.62
S.D.		53.23	40.67

Table 5: Forms and distribution of potassium in red soil series of Kavalur sub-watershed of Koppal district

Sl. No.	Red soil series	Water soluble K		Exchangeable K		Non-exchangeable K		Lattice K		Total K	
		(mg kg^{-1})									
		Surface soils	Sub-surface soils	Surface soils	Sub-surface soils	Surface soils	Sub-surface soils	Surface soils	Sub-surface soils	Surface soils	Sub-surface soils
1	BPR	2.22	2.16	172.76	140.84	764.96	853.89	22010.02	22789.11	22600	23500
2	GHT	1.68	1.30	117.80	96.31	444.42	516.54	14675.06	16281.07	15000	16700
3	HLK	2.12	2.02	111.60	106.13	628.10	676.93	17585.62	20931.22	18100	21500
4	KKR	4.08	2.24	136.04	102.67	356.77	692.61	18483.35	19312.30	18700	19900
5	KSP	2.96	2.04	97.43	85.71	561.79	639.30	16738.60	17748.45	17200	18300
6	MNL	2.84	1.68	145.48	133.09	511.62	538.94	18336.70	20995.83	18700	21400
7	MRD	3.64	2.88	148.32	112.33	376.54	430.98	16475.42	19784.23	16700	20100
8	TGR	2.32	1.84	137.27	112.55	564.48	654.75	19075.11	19859.64	19500	20400
Range		1.68-4.08	1.30-2.88	97.43-172.76	85.71-140.84	356.77-764.96	430.98-853.89	14675.06 - 22010.02	16281.07-22789.11	15000-22600	16700 - 23500
Mean		2.73	2.02	133.33	111.20	526.08	625.49	17922.49	19712.73	18312.50	20225.00
S.D.		0.81	0.45	23.76	18.24	135.29	129.59	2160.604	2014.834	2234.43	2070.71

Results and Discussion

The available potassium in red soil series varied from 221.00 to 389.00 kg ha^{-1} in surface soil and in sub-surface soil ranged from 194.00 to 317.00 kg ha^{-1}. The highest available potassium in both surface and sub-surface soil was recorded in BPR soil series and the lowest in KSP soil series respectively. The mean available potassium in surface soil was 300.87 kg ha^{-1} and in sub-surface soil was 250.62 kg ha^{-1}. The available potassium in red soil series was medium to high in status. BPR, MRD soil series shows higer potassium than KSP, GHT soil series. The variation in K status in red soil series might be due to cultural practices, application of fertilizers, organic manures and other inputs. The surface available potassium in soils was more compared to sub-surface. This may be due to the fact that in red soil series the kaolinite is dominant among secondary clay minerals followed by the smectite in the surface soils (Anjali, 2017) [1]. Adequate level of available K in red soils of the study area due to the prevalence of K-rich clay minerals like illite and kaolinite. In addition to secondary minerals, the soil also contained the primary minerals like mica (dominant) followed by quartz and feldspar in all the soil series of Kavalur sub-watershed (Anjali, 2017) [1].

The water soluble potassium in red soil series of Kavalur sub-watershed of Koppal district varied from 1.68 to 4.08 mg kg^{-1} with a mean of 2.73 mg kg^{-1} in surface soils. The sub-surface water soluble K content varied from 1.30 to 2.88 mg kg^{-1} with a mean of 2.02 mg kg^{-1}. The highest water soluble K of surface soil was obtained in KKR (4.08 mg kg^{-1}) soil series and in sub-surface soil was MRD (2.88 mg kg^{-1}) soil series. The lowest water soluble K in surface and in sub-surface soils was recorded in GHT (1.68 and 1.30 mg kg^{-1}) soil series. The water soluble potassium was high in surface soil of red soil series like KKR, MRD compared to sub-surface soils (fig.1). Higher amount of sand and organic matter present in surface soil contributed for high water-soluble K than sub-surface soil (Chahal *et al.*, 1976) [6].

The exchangeable potassium content of red soil series ranged from 97.43 to 172.76 mg kg^{-1} in surface soil, whereas, in sub-surface soils varied from 85.71 to 140.84 mg kg^{-1}.The highest was obtained in BPR (172.76 and 140.84 mg kg^{-1}) soil series for both surface and sub-surface soils (fig. 2). At both the soils the lowest value was recorded in KSP (97.43 and 85.71 mg kg^{-1}) soil series. The mean values of exchangeable K were 133.33 and 111.20 mg kg^{-1} in surface and sub-surface soil, respectively. The exchangeable potassium in surface soil was high because of K fertilization and application of manures enriched the exchangeable sites of clay-humus complex there by increased the exchangeable K content. The lower values of exchangeable K may be due to crop uptake and also less exchange sites available for potassium ions at deeper depths of the soil (Divya *et al*., 2016a) [7].

The non-exchangeable potassium of red soil series ranged from 356.77 to 764.96 mg kg^{-1} in surface soil and 430.98 to 853.89 mg kg^{-1} in sub-surface layer. The lowest was obtained in KKR (356.77 mg kg^{-1}) soil series and highest was obtained in BPR (764.96 mg kg^{-1}) soil series for surface soils. In sub-surface soil the highest was recorded in BPR (853.89 mg kg^{-1}) soil series and lowest in MRD (430.98 mg kg^{-1}) soil series. Non-exchangeable potassium is generally considered as slowly released K in soil for the plants under stress situation. MRD, HLK and other soil series shows the lower values of non-exchangeable potassium in the surface soils (fig. 3) indicates the rapid conversion of fixed form of potassium to available form to compensate the removal of available K by crop uptake in the surface soil of soils (Ranganathan and Sathyanarayana, 1980) [15].

The lattice potassium of red soil series ranged from 14675.06 to 22010.02 mg kg^{-1} in surface soils. The lattice potassium in sub-surface soils ranged from 16281.07-22789.11 mg kg^{-1}. Among the surface and sub-surface soils highest lattice potassium was obtained in BPR (22010.02 mg kg^{-1} and 22789.11 mg kg^{-1}) soil series and lowest in GHT (14675.06 and 16281.07 mg kg^{-1}) soil series for both surface and sub-surface soils. Mean values of the lattice potassium in red soil series were 17922.49 mg kg^{-1} and 19712.73 mg kg^{-1} in surface and sub-surface soils, respectively (fig. 4). The high values of 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 are in accordance with the findings of Divya *et al.* (2016a) [7] and Harsha and Jagadeesh (2017b) [9].

The total potassium in surface depth of red soil series varied from 15000 to 22600 mg kg^{-1} and in sub-surface soils ranged from16700 to 23500 mg kg^{-1}. The surface total K was recorded highest in BPR (22600 mg kg^{-1}) soil series and lowest in GHT (15000 mg kg^{-1}) soil series. The BPR (23500 mg kg^{-1}) and GHT (16700 mg kg^{-1}) soil series showed highest and lowest total K for sub-surface soils, respectively (fig. 5). BPR, HLK and other soil series shows higher total K content in sub-surface than surface soils (Fig.5a). Depending on clay mineralogy like 2:1 clay minerals, lattice K content and organic matter content, variation in the depth wise distribution of total potassium depends upon the relative effect of factors such as, soil texture, intensity of weathering of surface soils, organic carbon content and release of soluble potassium from organic residues, application of potassic fertilizers and leaching of potassium to lower horizons. The results are in comparison with those of research findings reported by Gali and Hebsur (2011) [8], Jagmohan and Grewal (2014) [11].

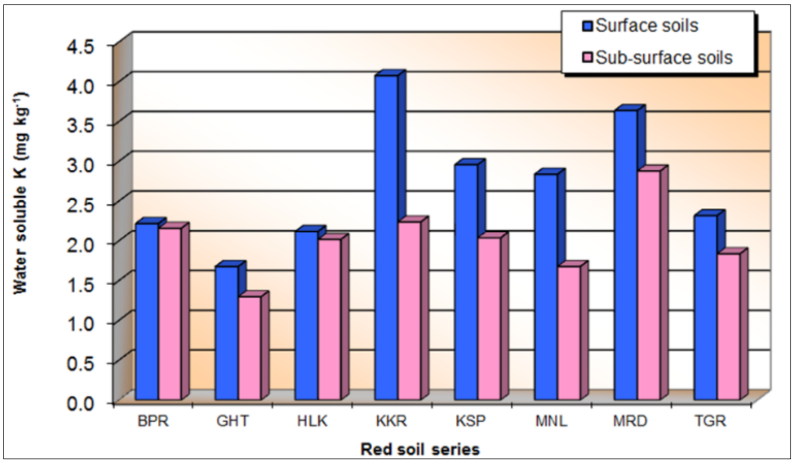

Fig 1: Water soluble K in surface and sub-surface soils of red soil series

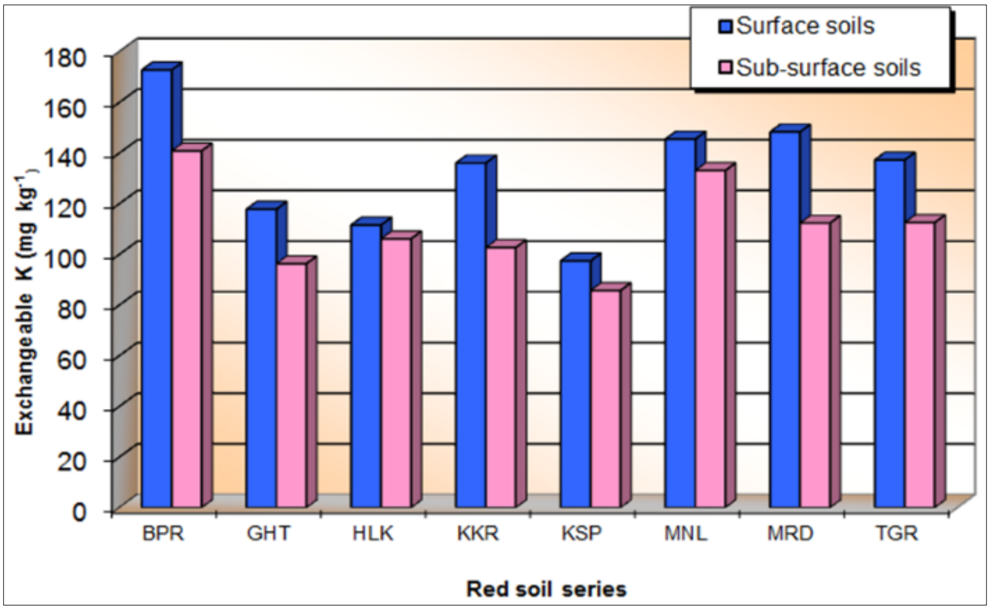

Fig 2: Exchangeable K in surface and sub-surface soils of red soil series

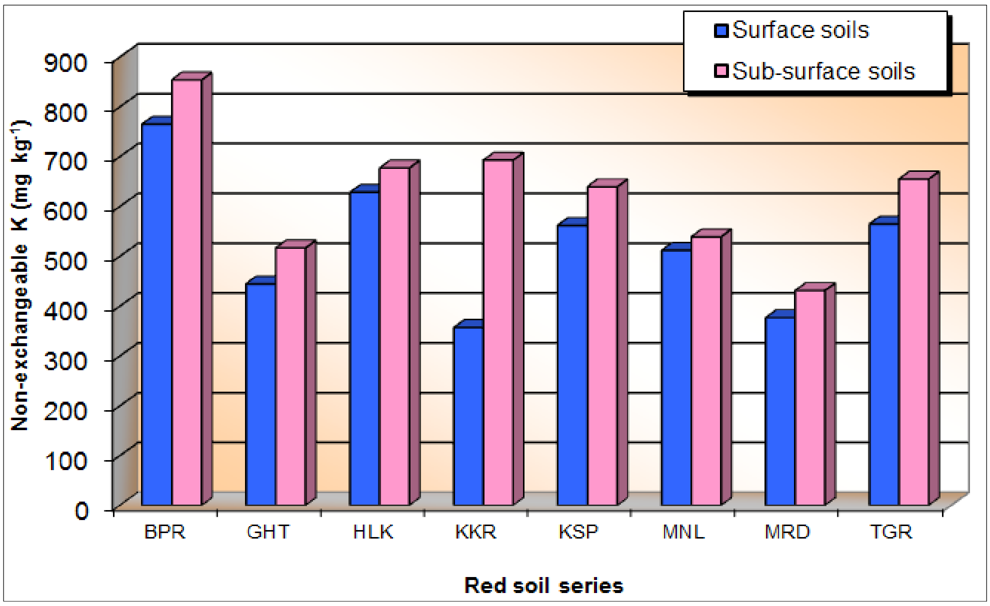

Fig 3: Non-exchangeable K in surface and sub-surface soils of red soil series

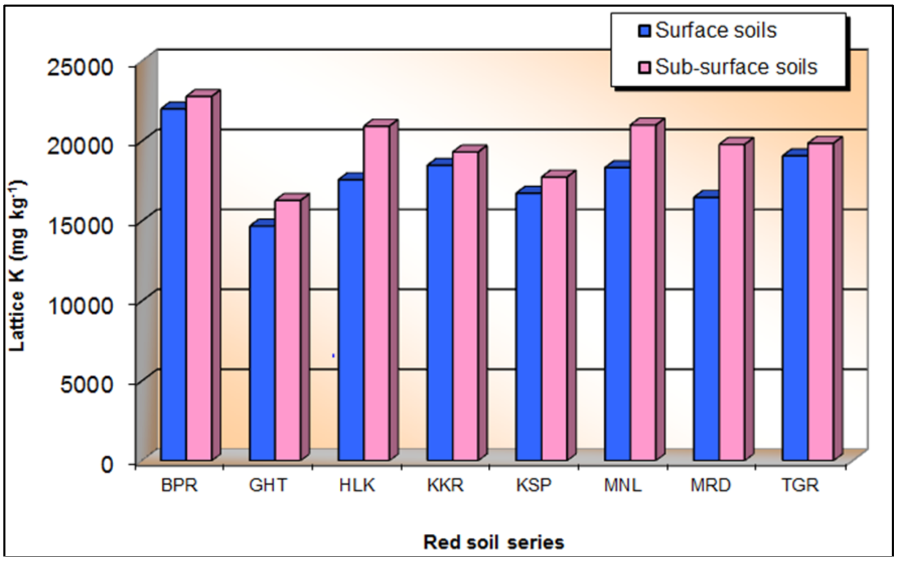

Fig 4: Lattice K in surface and sub-surface soils of red soil series

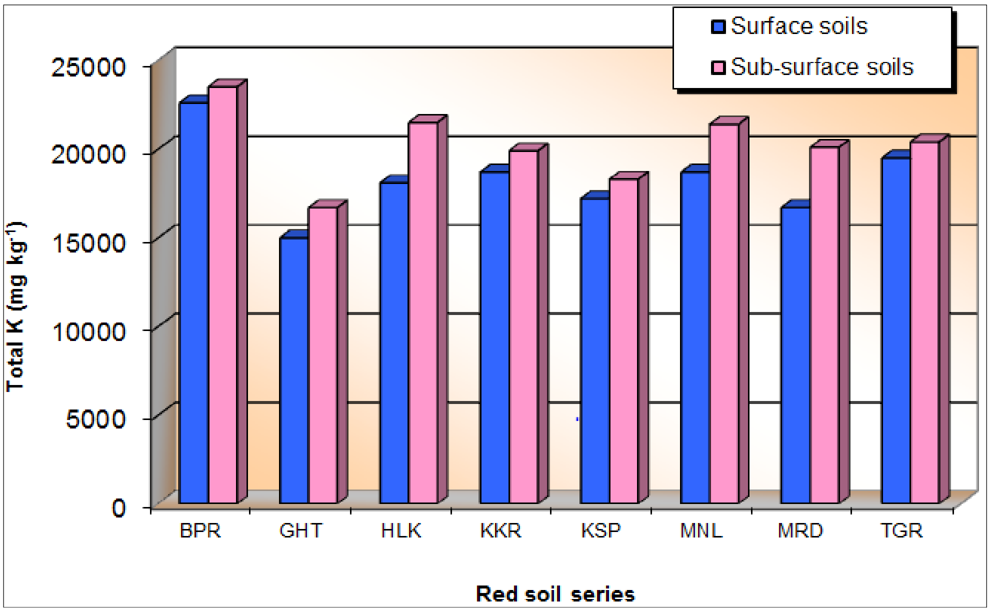

Fig 5: Total K in surface and sub-surface soils of red soil series

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.

References

1. Anjali MC. Characterization and mineralogy of soils of Kavalur sub-watershed (4D4A2P) of Koppal district of north Karntaka. Ph.D. Thesis, Univ. Agric. Sci., Dharwad, Karnataka (India), 2017.
2. Anonymous. Land resource atlas of Kavalur sub-watershed properties Sujala-III Project. Directorate of research, U. A. S. Dharwad, 2016.
3. Anonymous. Ground water information booklet, Koppal district, Karnataka. 2011; 13:23-29. www.cgwb.gov.in./district_profile/karnataka.
4. Brady Delhi NC, Weil RR. The Nature and Properties of Soils, 13th Ed. Pearson, 2002.
5. Black CA. Methods of Soil Analysis, part II, Chemical and Microbiological properties, No. 9 series, Agronomy, American Soc. Agron. Madison, Wisconsin, USA, 1965.
6. Chahal RS, Sangwan OP, Bharat S. Forms of potassium in some groundnut growing soils of Ambala and Gurgaon districts (Haryana). Bull. Indian Soc. Soil Sci. 1976; 10:61-65.
7. Divya M, Jagadeesh BR, Srinivasa DK, Yogesh GS. Effect of long term soil fertilizer application on forms and distribution of potassium in soil under rice-cowpea cropping system. Asian J Soil Sci. 2016a; 11(1):10-19.
8. Gali SK, Hebsur NS. Potassium dynamics in soils under different cropping systems of Karnataka. Soil Sci. Res. North Karnataka, 76th Annual Convention Indian Soc. Soil Sci, 2011, 85-89.
9. Harsha BR, Jagadeesh BR. Studies on distribution of potassium fraction in surface and sub-surface layers of black soils. J Pharmacognosy and Phytochem. 2017b; 26(6):1665-1669.
10. Jackson ML. Soil Chemical Analysis, Prentice Hall of India Pvt Limited, New Delhi, 1973.
11. Jagmohan S, Grewal KS. Vertical distribution of different forms of potassium and their relationship with different soil properties in some Haryana soil under different crop rotation. Adv. Pl. Agric. Res. 2014; 1(2):1-52, 23-54.
12. Knudsen D, Paterson GA, Pratt PF. Method of soil analysis., 2nd ed. Agronomy No.9. American Soc. Agron. Madison WI, 1982.
13. Lim CH, Jackson ML. Dissolution for total elemental analayasis, American Soc. Agron. 1982; 12:1-22.
14. Martin HW, Sparks DL. On behaviour of non-exchangeable potassium commun. Soil Sci. Plant Anal. 1985; 16:133-162.
15. Ranganathan A, Sathyanarayana J. Studies on potassium status of soils of Karnataka. J Indian Soc. Soil Sci. 1980; 28:148-153.