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Forms and Distribution of Potassium in Selected Maize Growing Soils of Haveri District of Karnataka, India

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A B S T R A C T

Potassium an important major nutrient exists in soil as different forms and these forms are in a state of quasi-equilibrium with each other. These different forms of potassium and their distribution were studied in twenty representative red and black soil types spreading over seven taluks of Haveri district of Karnataka. Soils were generally sandy clay loam to clay in texture. The soil reaction ranged between slightly acidic and near neutral in reaction and electrical conductivity was well within the permissible limit. The organic carbon content was low to medium. The average CEC, potassium adsorption ratio, sum of exchangeable cations and available potassium of black soils was high compared to red soils at both the depths. Results of the study indicated that all the forms of potassium found higher in black soils compared to red soils. The water soluble and exchangeable K was higher in surface sample compared to sub surface in both the soil type. Whereas, non-exchangeable, lattice and total K was higher in sub surface than the surface in both the soil types. The water soluble form of K showed a significant and positive correlation with sand in red (r= 0.755*) and black (r= 0.527*) soils. The exchangeable K was significantly and positively correlated with CEC (r= 0.721* and r= 0.807* in red and black soils, respectively) whereas, non-exchangeable K, lattice K and total K showed positive correlation for clay.

Introduction

The biotic cycling of potassium (K) in crop land systems has been relatively understudied in comparison with nitrogen (N) and phosphorus (P) despite its critical roles in maintaining the nutrition of primary production in crop plants. Maize growing soils in India commonly have high levels of potassium down to depths of more than one meter (Datta, 2011). Historically high removal rates by crops such as maize and cotton have depleted soil K pools and K deficiencies have been observed in crops.

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.

Potassium in soil can be allocated to three pools of availability for uptake by roots. It is dissolved in soil water, adsorbed onto particles of clay and organic matter and held within the crystal structures of feldspar and mica. The organic matter in soils contains a negligible amount of K because it is not a constituent of biomolecule, hence is easily and quickly leached from leaves due to its high solubility. However, the fraction of soil K directly available to plants (*i.e.*, in soil solution) is usually a small proportion (0.10-0.20 per cent) of the total soil K, whereas both the immediately available water-soluble fraction and the exchangeable fraction comprise 1.00-2.00 per cent and the soil-unavailable fractions 96-99 per cent (Britzke *et al.*, 2012).

Potash fertilizers are not effective for all soils and therefore before their application it is necessary to assess the amount of potassium in the soils which is to be fertilized and the degree of availability to plant. The K fertilization should be based on knowledge of quantity of K in various types and sub types of soils and not on general specifications based on crop requirement. 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 was under taken on K dynamics under maize cropping system in two soil types representing the major soils of Haveri district.

Materials and Methods

The surface (0-20 cm) and sub-surface (20-50 cm) soil samples were collected from fourty location belonging to seven taluks of maize growing areas in Haveri district of Karnataka. The soil samples were processed and analysed for pH (1:2.5) (Jackson, 1973), EC (1:2.5) (Jackson, 1973), OC by Walkley and Black's wet oxidation method (Piper 1996), CEC (Jackson, 1973), available potassium (Jackson, 1973), exchangeable cations (Jackson, 1973), EPP and PAR (U.S.D.A, 1954), particle size distribution (Jackson, 1973), water soluble K (1:5) (Black, 1965), exchangeable potassium was determined by extracting with *N N* NH_4OAc solution as outlined by Knudsen *et al.*, (1982). The water-soluble K was subtracted from NH_4OAc-K to get the exchangeable potassium content of the soil. The non-exchangeable K was estimated by boiling 1*N* HNO_3 method as outlined by Knudsen *et al.*, (1982). The quantity of K obtained with the NH_4OAc extract was subtracted to get the non-exchangeable potassium content in the soil. Total potassium content was determined by digesting the samples with hydrofluoric acid in a closed vessel (Lim and Jackson, 1982). The lattice potassium was computed as difference between total potassium and the sum of water soluble, exchangeable and non-exchangeable K fractions (Tables 1 and 2).

Results and Discussion

Physico-chemical properties of soil

The pH varied from slightly acidic to normal (6.38 to 7.85) in reaction. The red soils were having low pH (6.38) compared to black soils (Tables 3 and 4). In both the soil types, pH of sub surface samples was high compared to surface. The electrical conductivity in both the soil types was well within the permissible limits (< 1.0 dSm^{-1}). In both the soil types, EC increased with depth. The organic carbon content varied from low (4.50 g mg^{-1}) to high (7.98 g mg^{-1}). The organic carbon content in surface samples of black soil was high compared to red soils. The texture of soil varied from sandy clay loam to clay loam in texture for both the depths in red soils while that of black soils were clay loam to clay in texture in surface samples and clay in sub surface samples. The average CEC of black soils in surface layer was high (38.53 cmol (p^+) kg^{-1}) compared to red soils (20.72 cmol (p^+) kg^{-1}) (Table 5 and 6). In case of sub surface depth, average CEC of higher value was noticed in black soils (41.58 cmol (p^+) kg^{-1}) compared to red soils (23.62 cmol (p^+) kg^{-1}). The average values of sum of exchangeable cations was higher in black soils (35.64 cmol (p^+) kg^{-1}) and 38.84 cmol$(p^+)$$kg^{-1}$ in surface and sub-surface layers, respectively) compared to red soils (18.55 cmol (p^+) kg^{-1} and 22.07 cmol$(p^+)$$kg^{-1}$ in surface and sub-surface depths). The calcium and magnesium were dominant cation in both the soil type. The average values of exchangeable potassium percentage were high in red soils at both the depths (11.38 and 8.50 per cent in surface and sub-surface depths, respectively). The average value of potassium adsorption ratio was high in black soils at both the depths (2.25 and 1.34 in surface and sub-surface depths, respectively). The available potassium on an average obtained highest in black soils at both the depths (529.53 kg ha^{-1} and 327.04 kg ha^{-1} in surface and sub-surface depths, respectively) when compared to red soils (339.53 kg ha^{-1} and 281.44 kg ha^{-1} surface and sub-surface depths, respectively). In both the soil types, surface samples recorded high available potassium compared to sub surface.

Forms and distribution of potassium

The data related to forms and distribution of potassium in surface and sub-surface depths of red and black soils are presented in tables 7 and 8, respectively.

Water soluble K

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 (Table 7). 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 K of black soils ranged from 2.83 to 8.13 mg kg^{-1} in surface with a mean of 4.60 mg kg^{-1}. The water soluble potassium in sub surface layer varied from 2.00 to 6.23 mg kg^{-1} with a mean of 3.67 mg kg^{-1} (Table 8). The black soils recorded more water soluble K at surface as well as sub surface depths compared to red soils was due to the fact that black soils have greater moisture retention capacity and nutrient holding capacity than red soils and also organic matter content was relatively higher in these soils (Anil *et al.*, 2009).

Exchangeable K

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 mean value of exchangeable K was 52.28 and 45.24 mg kg^{-1} in surface and sub-surface layers, respectively. The exchangeable potassium in black soils varied from 48.92 to 100.96 mg kg^{-1} in surface and 36.90 to 78.40 mg kg^{-1} in sub surface. The mean content of exchangeable K was 56.00 and 46.81 mg kg^{-1} in surface and sub-surface samples, respectively.

The mean exchangeable potassium of black soils were high compared to red soils it may be due to fact that black soils are rich in organic matter content and in general, dominated by 2:1 type of clay minerals which offered more exchange sites for K. The results were in corroboration with that of Anil *et al.*, (2009), Gali and Hebsur (2011) (Fig. 1).

Non-exchangeable K

The average non-exchangeable potassium in surface soils of red soil type recorded 581.53 mg kg^{-1} and that of sub surface layer recorded 723.62 mg kg^{-1}.

Table.1 Details of soil samples collected from different places (red type) of maize growing areas 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 Details of soil samples collected from different places (black type) of maize growing areas of Haveri district, Karnataka

Sl. No.	Taluk	Location	Latitude	Longitude
1	Shiggoan	Bankapur-1	15° 02’ 52.1’’	75° 15’ 16.1’’
2	Shiggoan	Bankapur-2	15° 02’ 20.5’’	75° 15’ 55.0’’
3	Savanur	Kengapur	15° 01’ 21.3’’	75° 14’ 40.0’’
4	Savanur	Mannangi-1	14° 53’ 05.3’’	75° 17’ 39.7’’
5	Savanur	Mannangi-2	14° 52’ 58.7’’	75° 17’ 37.7’’
6	Savanur	Savoor	14° 53’ 42.8’’	75° 17’ 28.0’’
7	Haveri	Haveri	14° 53’ 45.0’’	75° 27’ 54.1’’
8	Haveri	Devihosur	14° 53’ 40.4’’	75° 29’ 41.7’’
9	Hangal	Hangal	14° 59’ 13.2’’	75° 57’ 32.5’’
10	Byadgi	Kaginelli	14° 51’ 28.2’’	75° 44’ 32.0’’
11	Hirekerur	Rattihalli-1	14° 51’ 18.2’’	75° 44’ 32.0’’
12	Hirekerur	Rattihalli-2	14° 51’ 36.3’’	75° 39’ 36.1’’
13	Hirekerur	Rattihalli-3	14° 51’ 21.0’’	75° 33’ 39.4’’
14	Hirekerur	Rattihalli-4	14° 52’ 29.9’’	75° 33’ 40.2’’
15	Hirekerur	Rattihalli-5	14° 49’ 32.0’’	75° 33’ 42.0’’
16	Hirekerur	Rattihalli-6	14° 49’ 34.2’’	75° 33’ 46.0’’
17	Hirekerur	Jogihalli-1	14° 45’ 10.6’’	75° 39’ 36.8’’
18	Hirekerur	Jogihalli-2	14° 52’ 48.8’’	75° 30’ 33.0’’
19	Hirekerur	Jogihalli-3	14° 52’ 52.1’’	75° 30’ 32.2’’
20	Hirekerur	Jogihalli-4	14° 45’ 14.0’’	75° 39’ 11.9’’

Table.3 Physico-chemical properties in selected maize growing red soils of Haveri district

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

Scl- Sandy clay loam, Cl- Clay loam

Table.4 Physico-chemical properties in selected maize growing black soils of Haveri district

Sample No.	$pH_{1:2.5}$		$EC_{1:2.5}$ (dS m^{-1})		OC (g kg^{-1})		Textural class	
	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	7.60	7.58	0.22	0.25	5.94	5.14	C	C
2	7.20	7.22	0.26	0.27	6.20	5.71	Cl	C
3	7.40	7.36	0.28	0.27	4.88	3.65	C	C
4	7.00	7.02	0.35	0.36	6.41	6.14	C	C
5	7.77	7.80	0.26	0.29	6.64	5.23	Cl	C
6	7.35	7.40	0.25	0.30	7.12	6.02	C	C
7	7.68	7.70	0.28	0.33	7.01	6.21	Cl	C
8	7.85	7.77	0.26	0.25	7.14	6.28	C	C
9	7.38	7.40	0.28	0.32	7.98	6.45	C	C
10	7.48	7.52	0.33	0.35	7.01	6.23	C	C
11	7.62	7.61	0.27	0.30	6.14	5.19	C	C
12	7.65	7.61	0.29	0.33	6.47	5.35	C	C
13	7.60	7.58	0.32	0.31	6.24	5.11	C	C
14	7.61	7.64	0.30	0.32	6.98	5.98	C	C
15	7.63	7.64	0.29	0.31	7.41	6.35	C	C
16	7.54	7.55	0.31	0.30	6.66	5.29	C	C
17	7.65	7.66	0.25	0.25	7.23	6.35	C	C
18	7.61	7.62	0.30	0.32	7.08	6.01	C	C
19	7.58	7.60	0.27	0.29	7.22	6.03	C	C
20	7.58	7.61	0.30	0.34	7.96	6.39	C	C
Range	**7.00-7.85**	**7.02-7.80**	**0.22-0.35**	**0.25-0.36**	**4.88-7.98**	**3.65-6.45**	**Clay loam to clay**	**Clay**
Mean	**7.53**	**7.54**	**0.28**	**0.31**	**6.78**	**5.70**		
S.D.	**0.19**	**0.18**	**0.031**	**0.035**	**0.72**	**0.69**		

Cl – Clay loam, C- Clay

Table.5 Cation exchange capacity, Exchangeable potassium percentage, Potassium adsorption ratio, Sum of exchangeable cations and available Potassium in selected maize growing red soils of Haveri district

Sample No.	CEC (cmol(p$^+$)kg^{-1})		Exchangeable potassium percentage (%)		Potassium adsorption ratio		Sum of exchangeable cations (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)**	**Surface (0-20 cm)**	**Sub surface (20-50 cm)**
1	15.21	19.26	14.33	10.69	2.23	1.73	14.19	17.75	328.56	268.82
2	19.34	25.98	12.92	8.12	1.91	0.74	18.01	25.44	376.32	256.20
3	23.65	26.48	8.75	7.43	1.08	0.90	20.83	24.96	274.30	228.80
4	19.36	20.45	10.95	9.33	1.94	1.69	17.93	18.20	321.12	272.40
5	16.92	19.37	12.47	8.01	0.89	0.63	15.36	18.67	271.80	225.24
6	21.86	24.89	9.88	6.38	1.51	0.81	19.84	23.40	312.96	237.42
7	24.15	25.94	14.49	9.63	2.98	1.90	22.59	24.07	483.84	376.32
8	16.88	20.31	12.14	7.48	0.89	1.01	15.24	19.44	302.16	258.60
9	26.32	27.78	8.32	7.23	2.12	1.94	23.85	25.46	322.56	298.20
10	16.22	19.32	15.41	11.95	2.67	1.41	14.64	18.21	430.08	321.56
11	22.76	24.97	9.27	7.20	1.10	1.03	19.80	24.41	268.80	215.04
12	27.05	28.92	9.24	8.50	1.65	1.21	24.13	27.00	430.08	366.38
13	18.43	21.22	11.93	7.49	1.85	0.84	16.27	19.37	341.26	295.04
14	20.29	24.68	10.74	8.14	1.37	1.03	18.70	23.92	302.54	261.35
15	17.21	19.23	13.07	10.41	1.38	0.87	15.22	18.22	323.51	271.80
16	24.83	27.54	8.17	7.15	1.92	1.15	22.50	25.31	371.32	298.13
17	18.36	22.78	10.89	6.58	0.95	0.71	16.34	21.11	269.80	235.04
18	17.86	20.05	17.35	14.96	2.07	1.54	16.51	18.92	374.82	342.96
19	23.14	27.16	9.20	7.43	2.21	1.51	20.62	25.49	376.22	320.76
20	24.66	26.09	8.15	5.97	1.36	1.09	22.38	24.88	308.56	278.81
Range	**15.21-27.05**	**19.23-28.92**	**8.15-17.35**	**5.97-14.96**	**0.89-2.98**	**0.63-1.94**	**14.19-24.13**	**17.75-27.00**	**268.80-483.84**	**215.04-376.32**
Mean	**20.72**	**23.62**	**11.38**	**8.50**	**1.70**	**1.19**	**18.55**	**22.07**	**339.53**	**281.44**
S.D.	**3.63**	**3.38**	**2.63**	**2.15**	**0.58**	**0.40**	**3.23**	**3.24**	**59.08**	**46.01**

Table.6 Cation exchange capacity, Exchangeable potassium percentage, Potassium adsorption ratio and Sum of exchangeable cations in selected Maize growing black soils of Haveri district

Sample No.	CEC (cmol(p^+)kg^{-1})		Exchangeable potassium percentage (%)		Potassium adsorption ratio		Sum of exchangeable cations (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)	Surface (0-20 cm)	Sub surface (20-50 cm)
1	44.98	47.84	14.33	10.69	2.23	1.73	14.19	17.75	430.28	344.00
2	27.14	30.14	12.92	8.12	1.91	0.74	18.01	25.44	426.64	268.87
3	35.45	38.78	8.75	7.43	1.08	0.90	20.83	24.96	452.81	324.21
4	40.16	42.27	10.95	9.33	1.94	1.69	17.93	18.20	483.84	313.66
5	23.64	26.34	12.47	8.01	0.89	0.63	15.36	18.67	376.32	298.10
6	42.54	45.65	9.88	6.38	1.51	0.81	19.84	23.40	420.08	319.60
7	24.26	27.39	14.49	9.63	2.98	1.90	22.59	24.07	483.84	368.20
8	42.21	46.05	12.14	7.48	0.89	1.01	15.24	19.44	489.27	313.60
9	41.89	44.95	8.32	7.23	2.12	1.94	23.85	25.46	322.56	224.00
10	33.14	35.76	15.41	11.95	2.67	1.41	14.64	18.21	432.08	366.31
11	44.25	46.82	9.27	7.20	1.10	1.03	19.80	24.41	645.12	448.00
12	42.27	44.08	9.24	8.50	1.65	1.21	24.13	27.00	645.12	494.20
13	32.74	36.75	11.93	7.49	1.85	0.84	16.27	19.37	591.36	443.04
14	38.18	42.74	10.74	8.14	1.37	1.03	18.70	23.92	537.60	413.60
15	41.85	44.06	13.07	10.41	1.38	0.87	15.22	18.22	722.64	488.85
16	42.06	43.94	8.17	7.15	1.92	1.15	22.50	25.31	698.88	403.24
17	41.21	44.58	10.89	6.58	0.95	0.71	16.34	21.11	591.36	358.40
18	43.86	47.24	17.35	14.96	2.07	1.54	16.51	18.92	483.84	393.67
19	42.18	43.72	9.20	7.43	2.21	1.51	20.62	25.49	596.15	463.62
20	46.78	52.61	8.15	5.97	1.36	1.09	22.38	24.88	752.64	592.80
Range	**23.64-46.78**	**26.34-52.61**	**8.15-17.35**	**5.97-14.96**	**0.89-2.98**	**0.63-1.94**	**14.19-24.13**	**17.75-27.00**	**322.56-752.64**	**224.00-592.80**
Mean	**38.53**	**41.58**	**11.38**	**8.50**	**1.70**	**1.19**	**18.55**	**22.07**	**529.53**	**327.04**
S.D.	**6.88**	**7.00**	**2.63**	**2.15**	**0.58**	**0.40**	**3.23**	**3.24**	**120.65**	**82.35**

Table.7 Forms and distribution of potassium in red soil type of selected maize growing areas 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 (0-20cm)	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**

Table.8 Forms and distribution of potassium in black soil type of selected maize growing areas 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	4.60	3.67	56.00	44.81	620.67	743.90	1.38	1.53	1.45	1.60
2	4.96	2.10	51.00	43.66	566.67	622.17	1.59	1.69	1.65	1.78
3	4.01	2.46	68.20	53.42	664.92	743.42	1.53	1.64	1.60	1.73
4	4.83	2.09	66.80	54.93	687.53	857.82	1.63	1.76	1.70	1.85
5	3.40	2.34	56.01	48.27	619.24	829.06	1.61	1.69	1.68	1.78
6	4.48	3.23	54.80	43.62	665.67	740.21	1.71	1.79	1.78	1.88
7	4.79	3.43	67.25	53.60	621.30	769.48	1.66	1.77	1.73	1.85
8	3.91	2.00	78.42	56.00	678.91	741.66	1.83	1.90	1.90	1.98
9	2.83	2.26	48.92	36.90	646.38	719.39	1.63	1.76	1.70	1.83
10	4.64	3.74	56.04	49.60	566.37	639.87	1.56	1.64	1.63	1.73
11	6.40	4.00	89.60	67.20	728.80	858.13	1.78	1.88	1.85	1.98
12	7.40	6.03	78.41	56.00	765.40	778.96	1.67	1.76	1.75	1.85
13	7.20	3.88	67.20	67.20	768.14	835.02	1.62	1.74	1.70	1.83
14	6.98	5.23	56.18	44.80	747.70	823.40	1.97	2.04	2.05	2.13
15	8.13	4.91	89.60	67.20	673.15	817.49	1.96	2.02	2.03	2.10
16	6.58	2.17	100.96	76.40	766.02	798.65	2.03	2.04	2.10	2.13
17	7.20	3.00	67.20	56.00	726.35	804.40	1.90	2.02	1.98	2.10
18	5.78	3.78	56.21	56.05	722.12	724.02	1.68	1.84	1.75	1.93
19	7.31	5.45	67.20	54.80	703.65	754.25	1.68	1.78	1.75	1.87
20	7.84	6.23	100.33	78.40	790.84	865.43	2.00	2.07	2.08	2.15
Range	**2.83-8.13**	**2.00-6.23**	**48.92-100.96**	**36.90-78.40**	**566.37-790.84**	**622.17-865.43**	**1.38-2.03**	**1.53-2.07**	**1.45-2.10**	**1.60-2.15**
Mean	**4.60**	**3.67**	**56.00**	**46.81**	**686.49**	**773.34**	**1.72**	**1.82**	**1.79**	**1.90**
S.D	**1.61**	**1.32**	**15.90**	**11.06**	**66.26**	**67.30**	**0.17**	**0.15**	**0.17**	**0.15**

Table.9 Correlation coefficients of different forms of K and selected soil properties in red soil type of maize growing areas of Haveri district

Forms of potassium	Correlation coefficients (r values)						
	pH	EC	OC	Sand	Silt	Clay	CEC
Water soluble K	0.460	-0.078	0.352	0.755*	0.345	0.227	0.128
Exchangeable K	0.496	0.161	0.378	-0.231	0.388	0.489	0.721*
Non-exchangeable K	-0.297	0.266	-0.020	-0.683**	0.239	0.868*	0.362
Lattice K	-0.293	0.100	-0.250	-0.443	0.502**	0.813*	0.422
Total K	0.310	0.106	0.248	-0.432	0.397	0.894*	0.412

**Significant at 1% level of significance; * Significant at 5% level of significance

Table.10 Correlation coefficients of different forms of K and selected soil properties in black soil type of maize growing areas of Haveri district

Forms of potassium	Correlation coefficients (r values)						
	pH	EC	OC	Sand	Silt	Clay	CEC
Water soluble K	0.235	-0.233	0.487	0.527*	0.442	0.260	0.369
Exchangeable K	0.283	0.218	0.391	-0.513*	0.454	0.563*	0.807*
Non-exchangeable K	0.252	0.287	-0.147	-0.559**	0.363	0.556*	0.259
Lattice K	-0.284	0.199	-0.314	-0.365	0.510**	0.959*	0.354
Total K	0.292	0.203	0.514**	-0.371	0.517**	0.965*	0.358

**Significant at 1% level of significance; * Significant at 5% level of significance

Fig.1 Water soluble and exchangeable potassium in Red and Black soils of selected maize growing areas of Haveri district

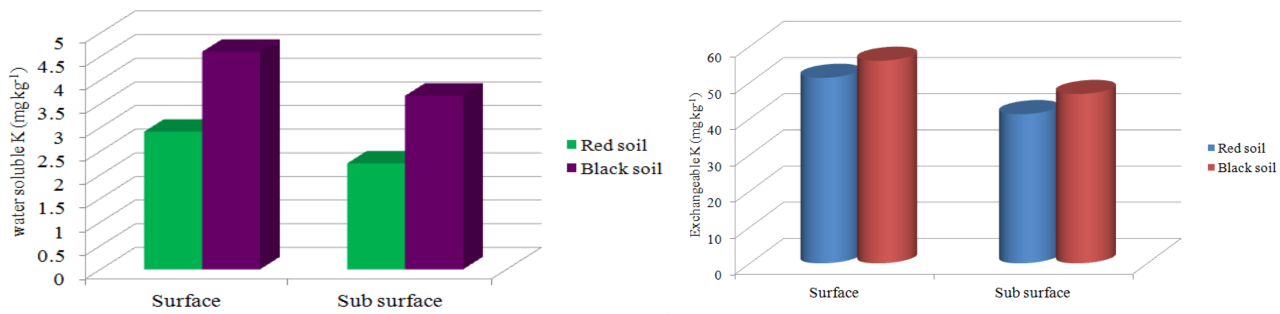


Fig.2 Non-exchangeable and lattice potassium in Red and Black soils of selected maize growing areas of Haveri district

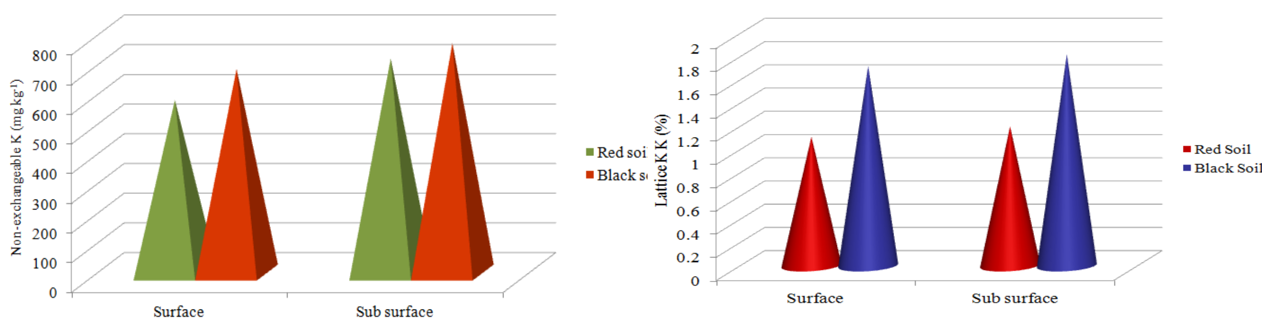
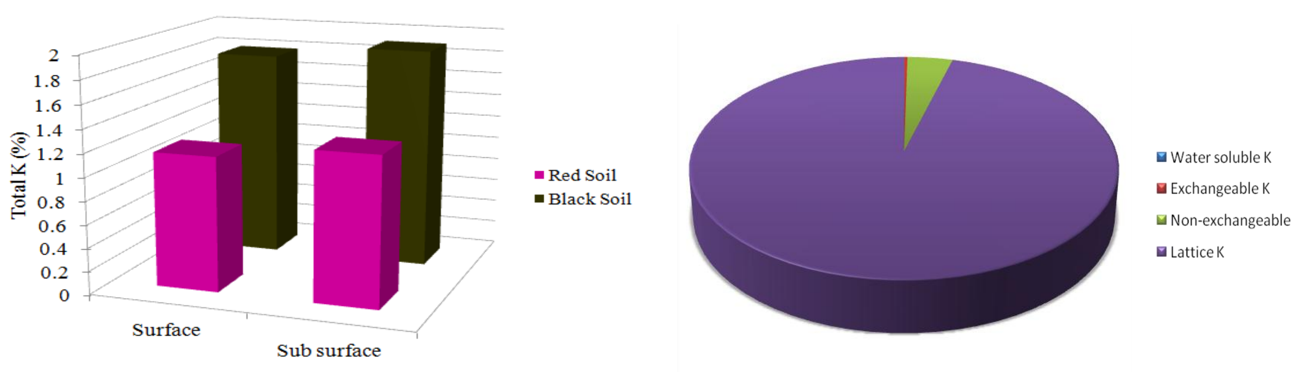


Fig.3 Total potassium and its distribution in red and black soils of selected maize growing areas of Haveri district



The average non-exchangeable potassium of surface layer in black soil type recorded 686.49 mg kg^{-1} and that of corresponding sub surface recorded 773.34 mg kg^{-1}. The non-exchangeable K was low in surface 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) and Divya *et al.,* (2016). However, the non-exchangeable K content of black soil was more compared to red soils at both the depths may be because of nature and amount of clay present in black soils (Hebsur and Gali, 2011 and Kundu *et al.,* 2014).

Lattice potassium

The mean values of lattice K in black soils was high (1.72 and 1.82 per cent in surface and sub-surface samples, respectively) compared to red soils (1.11 and 1.20 per cent in surface and sub-surface samples, respectively). The higher 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 and soil type 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) (Fig. 2).

Total K

The average values of total K was high in black soils (1.79 and 1.90 per cent in surface and sub-surface samples, respectively) compared to red soils (1.16 and 1.28 per cent in surface and sub-surface samples, respectively). The total K followed a trend of increase with depth. The black soils were rich with average total potassium compared to red soils irrespective of depth. It may be because of the rich K-bearing minerals in their lattice structure (Anil *et al.,* 2009). 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 were in comparison with those of research findings of Gali and Hebsur (2011), Jagmohan and Grewal (2014) and Divya *et al.,* (2016) (Fig. 3).

Correlation studies

Correlation (r-values) studies among different forms of potassium and soil properties

The correlation values for different soil properties and soil K forms in selected soil types are presented in tables 9 and 10, respectively.

In both red and black soil types, the water soluble K showed a positive correlation with sand (r= 0.755* and 0.527*). It may be due to fact that K ion present on sand particle can come easily into solution. The exchangeable K was positively and significantly correlated with clay it may be because of higher content of K bearing minerals present which might be having higher exchangeable surface.

The exchangeable K showed a positive correlation CEC and pH which may due be due to fact that increases in pH results in increase in CEC, which in turn might have increased exchangeable K. The non-exchangeable K was significantly and positively correlated with clay (r= 0.868*&0.556*) as clays have greater ability to fix K in non-exchangeable form. The sand fraction was negatively and significantly correlated with non-exchangeable K. It may be due to fact that sand particles lack fixation sites because of their coarse nature.

The lattice K was significantly and positively correlated with clay and silt which may be due to presence of K bearing minerals in clay and silt fractions. Similar trend followed for total K as that of lattice K as much of lattice K is contributed to total K and finer fractions of soils rich in K-bearing minerals as it is evident from the correlation coefficients. The present results were in agreement with the findings of Jagadeesh (2003), Kundu *et al.,* (2014), Jagmohan and Grewal (2014) and Hemlata (2016).

The results of the investigation suggested that in the Haveri district of Karnataka, maximum K content of the soils is in the non-exchangeable form, mostly fixed up within the clay lattice rendering very small amount of available K to plant. The forms of potassium were significantly correlated among different physic-chemical properties. 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 programme for a given set of soil and crop. A future study on clay mineralogical make-up may help in calibrating the reserve pool of K and the extent of its mining. This helps the planners to formulate an effective K fertilizer programme for the soils of the region.

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