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Original Research Article

Fractions of Potassium in Soils of Agriculture College Research Farm, Indore, Madhya Pradesh, India

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A B S T R A C T

A study was carried out on the fractions of potassium (K) in surface (0-15 cm) and sub-surface (15-30 cm) soils of Agriculture College research farm, Indore, Madhya Pradesh, India during 2015. The soil samples were analyzed for some physicochemical properties and different forms of potassium (K) *viz.* water soluble K, exchangeable, available K, non-exchangeable K, lattice K, and total K. Total 90 soil samples (45 surface and 45 sub-surface) from the 45 fields of college research farm, Indore were collected. The texture of the soil samples varied from silty clay to clay. The mean values of pH were 7.57 and 7.54 for surface and sub-surface soil samples, respectively. About 66.67% surface and 68.89% sub-surface soil samples belonged to low status (< 0.5%) of OC. The nitrogen (N) status was also low in surface and sub-surface soil samples (150-250 kg ha^{-1}). Available phosphorous (P) content was low to medium status in both depths of soil. The amount of water soluble, exchangeable, available, non-exchangeable, lattice and total K in different fields ranged from 4.20-36.00, 167-329.20, 212.10-347.00, 180.40-430.40, 8113.80-15823.60, 8550.50-16490.60 mg kg^{-1} with mean value of 14.77, 256.10, 271.86, 305.08, 12285.10, 12855.24 mg kg^{-1} in surface soils and 3.60-36.20, 184.10-335.70, 195.60-352.40, 208.80-395.80, 8922.80-16172.20, 9445.60-16785.60 mg kg^{-1} with mean value of 15.94, 250.89, 266.82, 305.19, 12142.70, 12714.73 mg kg^{-1} respectively in sub-surface soils. The water soluble, exchangeable, available, non-exchangeable and lattice K constituted 0.05-0.22, 1.95-2.00, 2.10-2.48, 2.10-2.60 and 94.90-95.95 per cent in surface soils and 0.03-0.22, 1.95-1.99, 2.07-2.10, 2.21-2.36 and 94.50-96.35 per cent in sub-surface soils to the total K respectively. Electrical conductivity in surface and sub-surface soil showed highly significant positive correlation with exchangeable (r=0.529**, r=0.571**), available (r=0.574**, r=0.588**), lattice (r=0.528**, r=0.570**) and total K (r=0.531**, r=0.569**). A highly significant positive relationship was also observed between different forms of K.

Keywords

K fractions, Available K, Exchangeable K, Non-exchangeable K, Lattice K and total K.

Introduction

Potassium (K) is known as quality element and required by plants for healthy growth, but Indian agriculture has traditionally relied on the native soil resource of potassium. It constitutes an average of 1.9% of the earth crust (Tisdale *et al.*, 1985). It is an essential macro elements required for growth and development of plants, animals, and human beings also. Soil K is known to exist in different forms *viz.*, water soluble, exchangeable, non-exchangeable and as a part of mineral lattice. Water soluble and exchangeable forms of potassium are prime importance as far as their availability is concern to plants. There is a dynamic equilibrium among different forms of soil potassium and any depletion in a given form would shift the equilibrium in the direction to replenish it (Ramamoorthy and Velayutham, 1976). However, under certain circumstances the rate of replenishment may not be rapid enough to meet the crop need. The knowledge of different forms of K in soil and their vertical distribution in soils assist in assessing long term K availability and making judicious fertilizer recommendations for efficient crop production. Comparison of results presented in different reviews dealing with status of potassium in Indian soils (Hassan, 2002; Srinivasarao *et al.,* 2010), indicated that during the last two decades low available K category soils has virtually remained the same while the high area has decreased. Growing of continuous cropping without adequate application of K may leads to depletion of all forms of K and subsequent degradation of clay and silt minerals. This will adversely affect the K dynamics and may cause the constraints for crop production in the post green revolution era. Potassium is probably the most pertinent nutrient that has the potential of significantly affecting agricultural production in the country. Historically, low application rates of K in crop have led to over-dependence on the native soil reserve K (Sarkar *et al.,* 2014). The study area of Agriculture College farm, Indore belongs to Malwa Plateau agro-climatic zone and having medium to deep black soils belonging to Vertisols. These soils are dark grey-brown to dark greyish brown colour with black shades (Tamgadge *et al.,* 1999). Due to variation in topography and cropping sequence in this zone, various forms of K may change and affects its availability in soil. Relative abundance of different forms of soil K determines its supplying capacity and availability to crops. Cropping without potassium application deplete plant available K in soils in the long run and more rapidly so at high fertility levels (Biswas *et al.,* 1977). Knowledge of quantitative magnitude of different K forms in soils and interrelationship among them is important for the assessment of long term availability of K in soils. Scanty information is available on physical and chemical properties, different forms of K. Therefore, an attempt was made to assess the soil properties and different forms of K.

Materials and Methods

For the present investigation, total 90 soil samples from the 45 fields (0-15 cm and 15-30 cm depths) as surface and sub-surface samples of college research farm, Indore, Madhya Pradesh, India were collected during 2015. At each location soil was collected from four places, mixed thoroughly and reduced to get a representative sample by quartering. Collected soil samples were air dried and ground to pass through a 2 mm sieve. The soil samples were analyzed for pH and EC using standard methods suggested by Chapmam (1965). Soil organic carbon (OC), available nitrogen (N) and available potassium (K) were determined using standard methods (Jackson, 1973). For estimation of available P, soil samples were extracted as per Olsen *et al.,* (1954). Total K in soil samples was determined in HF-$HClO_4$ digests (Black, 1965). Water soluble K was determined by shaking the soil with distilled water (1:5 ratio). The 1N boiling HNO_3 extractable K was estimated by using flame photometer in 1:10, soil: acid suspension boiled for 10 minutes as described by Wood and DeTurk (1941). Non-exchangeable K was calculated by subtracting available K from 1N boiling HNO_3 extractable K. The amount of K in mineral lattice was calculated by subtracting

1N boiling HNO_3 extractable K from total soil K. The data were analyzed statistically as per the procedure given by Panse and Sukhatme (1961).

Results and Discussion

Soil properties

Irrespective of soil depth, the average pH and EC values of soils varied from 7.01 to 7.84 and 0.14 to 1.77 dS m^{-1}, respectively. Thus, the soils were alkaline in reaction without much accumulation of soluble salts (Table 1). Little accumulation of soluble salts are present in the surface and sub-surface soil samples due to basaltic parent material from which these soils are formed. The pH values of surface soil samples were found in the range of 7.11-7.84 under different fields with the mean value of 7.57 and sub-surface soil pH was found in the range of 7.01-7.83 with the mean value of 7.54 (Table 1). Maximum value of surface soil pH (7.84) was observed in 23rd field whereas minimum surface soil pH (7.11) was noticed in 11th field. About 40% and 60% surface soil samples were found in medium (pH 7-7.5) and high pH (> 7.5) values respectively. Maximum value of sub-surface soil pH (7.83) was observed in 12th field whereas, minimum sub-surface soil pH (7.01) was noticed in 29th field. About 33.33% and 66.67% sub-surface soil samples were found in medium and high pH values respectively. The higher pH could be due to increase in accumulation of exchangeable sodium and calcium carbonate. Because these soils are generally formed from the basic parent materials and having higher pH values.

Surface soil organic carbon status of Indore agriculture college farm (Table 1) was found in the range of 0.30-0.68% under different fields with the mean value of 0.46%. Maximum value of organic carbon (0.68%) in the surface soil was observed in 35th field whereas minimum value (0.26%) found in 23rd field. Sub-surface soil organic carbon status was found in the range of 0.20-0.63% with the average value of 0.45%. Maximum value of sub-surface soil organic carbon (0.63%) was observed in 28th field whereas minimum value (0.20%) was noticed in the 1st field. The data clearly shows, that 66.67% surface soil samples and 68.89% sub-surface soil samples belongs to low status (<0.5%) and 33.33% surface soils and 31.11% subsurface soil samples shows medium status (0.5-0.75%) of organic carbon. According to Muhr *et al.,* (1965) rating limits 56% of soils are low (<0.5%), 44% in medium (0.5-0.75%) and none of the soil samples were found in high (>0.75%) in organic carbon content in medium black soils. The low organic carbon content in these soils may attribute to the high rate of organic matter decomposition under hyperthermic temperature regime which leads to extremely high oxidising conditions. The surface soils contained higher amount of organic carbon possibly due to incorporation of huge amount of plant residues in surface soils.

The available N and P contents ranged from 125.87-232 kg ha^{-1} and 8.20-14.36 kg ha^{-1} with an average of 196 kg ha^{-1} and 10.51 kg ha^{-1} in surface soils, and 95-255 kg ha^{-1} and 8.16-12.76 kg ha^{-1} with an average of 197.6 kg ha^{-1} and 10.45 kg ha^{-1} in sub surface soils, respectively. The soils were poor with respect to N availability. The available N and P contents in the soils decreased with increasing depth, possibly due to high amount of organic matter in surface soils. These results are in agreement with those of Somasundaram *et al.,* (2009). The changes in the availability of N and P in experimental farm soils might be due to the variation of organic carbon status the soils.

Fractions of potassium

The available K content of surface and sub-surface soils varied from 212.1 to 347.0 mg kg^{-1} and 195.6 to 352.4 mg kg^{-1} with a mean value of 271.86 mg kg^{-1} and 266.82 mg kg^{-1} respectively. The water soluble K and exchangeable K contributed about 5.62 and 94.38 % in surface soils and 5.97 and 94.03 % in sub surface soils towards available K, respectively. Considering 49.01 mg kg^{-1} available soil K as the critical level for crops (Murthy and Hirekerur, 1980) none of these soils was deficient in available soil K. On an average, available soil K constituted only 2.11 and 2.09 % of total soil K in surface and surface soils respectively. Shilpa *et al.*, (2007) also reported that available K contributed 1.97% towards total K in soils. In general, available soil K was the highest in the surface soils but decreased in sub surface layers.

The water soluble K in surface and sub-surface layers of these soils ranged from 4.20-36.0 and 3.60-36.2 mg kg^{-1} with an average of 14.77 and 15.94 mg kg^{-1} respectively. Exchangeable K in surface and sub-surface soils varied from 167.0-329.2 and 184.1-335.7 mg kg^{-1} with an average of 256.1 and 250.89 mg kg^{-1} respectively (Table 2). Exchangeable K constituted about 2% of the total K both in surface and sub-surface soils. Non-exchangeable K varied from 180.4-430.4 and 208.8-396.8 mg kg^{-1} with an average of 305.08 and 305.19 mg kg^{-1} in surface and sub-surface soil layers, respectively. Non exchangeable K constituted 2.37 and 2.40% of the total K in surface and sub-surface soils respectively. More than 95% of the total K constituted by lattice portion of K The total K content of the soils varied from 8550.5-16490.6 mg kg^{-1} in surface soils and 9445.6-16785.6 mg kg^{-1} in sub-surface soils with mean values of 12855.24 and 12714.73 mg kg^{-1} respectively (Table 3). The variation in depth wise distribution of K fractions might be due to variation in mineralogical composition and degree of mineral weathering (Prasad 2010).

Relationship with soil properties

The results (Table 4) indicate that, in surface soil, pH showed negative correlation with all the forms of potassium except water soluble potassium and the coefficient of correlation of pH with exchangeable K (r= -0.398^{**}), lattice K (r= -0.405^{**}) and total K (r= -0.405^{**}) were significant at 1% level of significance whereas, available K (r= -0.330^{*}) and non-exchangeable K (r= -0.293^{*}) were significant at 5% level. In sub-surface soil, pH showed negative relationship with all the forms of potassium but level of significance is non-significant. In general, electrical conductivity (EC) of surface and sub-surface soil showed positive relationship with all the forms of potassium. In surface soil the coefficient of correlation of electrical conductivity with exchangeable K ($r=0.529^{**}$), available K ($r=0.574^{**}$), lattice K ($r=0.528^{**}$) and total K ($r=0.531^{**}$) were significant at 1% level of significance whereas, non-exchangeable and water soluble forms of potassium were not reached up to the level of significance. But in sub-surface soil the coefficient of correlation of EC with exchangeable K ($r=0.571^{**}$), available K ($r=0.588^{**}$) lattice K ($r=0.570^{**}$) and total K ($r=0.569^{**}$) were significant at 1% level. Non-exchangeable K and water soluble K was not reached up to the level of significance with EC. Koria *et al.*, (1989) has also reported similar relationship of these fractions with electrical conductivity (EC) of soil.

The organic carbon (OC) content of surface samples showed positive relationship with water soluble K, available K, lattice K and total K.

Table.1 The pH, EC, OC, available N and P in the soils at different research fields of agriculture college, Indore

Field No.	pH (1:2)		EC (dSm^{-1})		OC (%)		Available N (kg ha^{-1})		Available P (kg ha^{-1})	
Depth	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 Cm	15-30 cm	0-15 cm	15-30 cm
1	7.72	7.63	0.36	0.38	0.35	0.20	166.25	95.00	11.88	11.36
2	7.72	7.74	0.53	0.48	0.42	0.43	186.75	193.50	12.68	12.76
3	7.67	7.63	0.59	0.41	0.47	0.45	211.50	202.50	12.28	10.40
4	7.72	7.65	0.33	0.55	0.42	0.40	189.00	180.00	13.00	11.88
5	7.42	7.68	0.38	0.32	0.42	0.50	186.75	200.00	11.28	11.48
6	7.66	7.53	0.51	0.45	0.52	0.37	208.00	175.75	10.52	9.72
7	7.67	7.56	0.61	0.48	0.43	0.48	191.25	216.00	9.32	11.12
8	7.35	7.64	0.51	0.49	0.49	0.47	222.75	211.50	9.80	10.12
9	7.51	7.52	0.37	0.39	0.48	0.42	218.25	189.00	8.24	8.20
10	7.42	7.46	0.48	0.38	0.30	0.46	142.50	209.25	13.68	11.92
11	7.11	7.58	0.56	0.41	0.53	0.37	212.00	178.13	9.88	8.16
12	7.46	7.83	0.32	1.64	0.43	0.55	191.25	220.00	12.52	11.08
13	7.36	7.37	1.43	1.11	0.54	0.50	214.00	200.00	14.36	8.56
14	7.38	7.50	1.10	0.44	0.53	0.44	212.00	198.00	14.16	9.72
15	7.45	7.45	0.76	1.77	0.50	0.53	200.00	210.00	11.40	19.20
16	7.64	7.40	0.19	0.40	0.46	0.36	207.00	171.00	10.20	10.76
17	7.47	7.59	0.26	0.23	0.52	0.62	208.00	230.63	8.40	9.04
18	7.48	7.42	0.26	0.23	0.42	0.24	186.75	114.00	10.08	11.68
19	7.35	7.64	0.23	0.23	0.32	0.37	149.63	178.13	8.20	8.87
20	7.47	7.52	0.25	0.28	0.41	0.45	182.25	204.75	9.28	10.32
21	7.45	7.39	0.28	0.26	0.39	0.49	185.25	222.75	9.43	8.16
22	7.36	7.35	0.21	0.22	0.35	0.42	166.25	186.75	9.55	8.63
23	7.84	7.38	0.25	0.25	0.26	0.34	125.87	161.50	9.44	11.36
24	7.39	7.32	0.25	0.23	0.46	0.36	209.25	173.37	8.84	8.96
25	7.49	7.48	0.24	0.22	0.46	0.49	209.25	222.75	9.32	9.68
26	7.32	7.35	0.99	1.08	0.45	0.50	204.75	200.00	8.96	9.43
27	7.73	7.60	0.42	0.26	0.62	0.46	230.63	209.25	10.56	10.84
28	7.67	7.67	0.28	0.29	0.46	0.63	209.25	234.37	10.12	10.48
29	7.78	7.01	0.14	0.31	0.33	0.29	154.37	225.00	9.88	10.16
30	7.69	7.77	0.24	0.28	0.60	0.54	216.00	216.00	9.12	9.32
31	7.45	7.38	0.29	0.29	0.54	0.49	220.50	180.50	9.80	9.44
32	7.73	7.56	0.31	0.31	0.38	0.47	213.75	222.00	8.32	8.56
33	7.83	7.26	0.29	0.31	0.55	0.45	204.75	226.00	9.48	9.88
34	7.54	7.68	0.31	0.35	0.56	0.56	224.00	255.00	12.36	13.76
35	7.75	7.56	0.44	0.31	0.68	0.49	220.50	225.00	11.36	10.20
36	7.54	7.73	0.32	0.32	0.60	0.33	156.75	149.63	10.64	11.40
37	7.64	7.53	0.29	0.31	0.32	0.58	232.00	232.00	10.08	10.52
38	7.68	7.80	0.40	0.39	0.39	0.53	187.63	210.00	10.84	8.88
39	7.78	7.52	0.59	0.33	0.42	0.43	186.75	193.50	11.80	11.04
40	7.55	7.57	0.28	0.31	0.34	0.53	161.50	210.00	10.00	10.52
41	7.62	7.58	0.29	0.29	0.53	0.43	210.00	193.50	11.36	10.96
42	7.74	7.71	0.30	0.28	0.49	0.36	220.50	173.37	10.32	10.72
43	7.69	7.67	0.30	0.30	0.48	0.53	216.00	210.00	9.28	8.20
44	7.70	7.32	0.39	0.29	0.33	0.36	156.75	171.00	10.52	11.84
45	7.65	7.67	0.31	1.08	0.55	0.53	222.00	212.00	10.32	10.84
Range	7.11-7.84	7.01-7.83	0.14-1.43	0.22-1.77	0.26-0.68	0.20-0.63	125.87-232	95-255	8.20-14.36	8.16-12.76
Average	7.57	7.54	0.41	0.44	0.46	0.45	196.23	197.60	10.51	10.45

Table.2 Water soluble, exchangeable and available K in the soils at different research fields of agriculture college, Indore

Field No.	W.S.K (mg kg^{-1})		Ex. K (mg kg^{-1})		Avail. K (mg kg^{-1})	
Depth	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
1	16.90	12.10	310.40	319.90	327.30	332.00
2	20.90	9.90	315.80	282.60	336.70	292.50
3	36.00	23.50	282.30	213.30	318.30	236.80
4	20.70	36.20	251.70	269.20	272.40	305.40
5	9.90	22.10	275.60	223.50	285.50	245.60
6	7.10	4.70	308.30	320.20	315.40	324.90
7	11.20	5.20	311.60	321.90	322.80	327.10
8	23.60	4.80	293.30	321.00	316.90	325.80
9	5.00	6.80	241.40	301.70	296.40	308.00
10	8.90	4.80	277.40	271.00	286.30	275.80
11	7.50	7.00	305.60	292.70	313.10	299.70
12	4.20	15.40	253.50	306.40	257.70	321.80
13	14.50	17.90	321.60	318.50	336.10	336.40
14	14.10	11.60	298.50	255.20	312.60	266.80
15	24.30	13.90	294.20	307.70	318.50	321.60
16	22.90	11.40	245.50	260.20	268.40	271.60
17	12.10	10.00	236.40	249.00	248.50	259.00
18	11.20	3.60	244.60	260.70	250.80	264.30
19	19.00	18.40	281.00	216.10	250.00	234.50
20	12.90	12.90	228.80	234.00	241.70	246.90
21	16.60	9.60	218.40	220.40	235.00	230.00
22	15.5	17.00	219.10	220.20	234.60	237.20
23	9.70	26.60	240.30	248.00	250.00	274.60
24	8.30	34.40	301.30	264.60	309.60	299.00
25	9.70	19.80	328.80	305.50	338.50	325.30
26	17.80	32.10	329.20	309.00	347.00	341.10
27	22.40	15.10	243.50	210.80	265.90	225.90
28	11.40	30.10	272.60	210.50	284.00	240.60
29	9.80	14.70	257.20	233.10	266.80	247.80
30	10.00	16.60	212.00	217.30	222.00	233.90
31	18.40	15.70	232.50	235.80	250.90	251.50
32	10.40	17.70	201.70	202.50	212.10	220.20
33	27.40	12.70	204.30	215.90	231.70	228.60
34	14.00	9.90	224.30	214.00	238.30	223.90
35	11.40	10.00	228.50	195.10	239.90	205.10
36	10.30	11.50	230.20	184.10	240.50	195.60
37	13.30	11.30	211.20	196.80	224.50	208.10
38	21.10	16.60	200.90	246.90	222.00	263.50
39	17.70	24.50	222.40	224.80	240.10	249.30
40	26.40	19.10	212.00	212.70	238.40	231.80
41	9.60	15.90	211.20	188.90	220.80	204.80
42	7.30	19.30	167.00	203.90	224.30	223.20
43	11.20	21.40	225.60	215.70	236.80	237.10
44	8.70	26.90	261.70	233.00	270.40	259.90
45	23.60	16.70	290.50	335.70	314.10	352.40
Range	4.20-36.00	3.60-36.2	167-329.2	184.1-335.7	212.1-347.0	195.6-352.4
Average	14.77	15.94	256.10	250.89	271.86	266.82

Table.3 Non-exchangeable, lattice and total K in the soils at different research fields of agriculture college, Indore

Field No.	Non-ex. K (mg kg^{-1})		Lattice K (mg kg^{-1})		Total K (mg kg^{-1})	
Depth	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
1	276.80	239.00	14916.80	15424.70	15520.90	15995.70
2	383.00	355.20	15370.60	13782.70	16090.30	14430.40
3	317.20	359.80	13495.10	13518.70	14130.60	14115.30
4	270.40	224.40	10523.00	12455.70	11065.80	12985.50
5	430.40	305.60	13064.30	10624.70	13780.20	11175.90
6	388.00	395.80	14712.20	15289.70	15415.60	16010.40
7	346.20	376.40	15111.70	15591.80	15780.70	16295.30
8	316.80	335.40	14032.10	15489.10	14665.80	16150.30
9	376.60	376.20	11447.40	14400.50	12070.40	15085.20
10	379.00	332.00	13305.30	12942.70	13970.60	13550.50
11	272.60	345.80	14894.90	14189.90	15480.60	14835.40
12	305.60	310.60	12112.60	14688.40	12675.90	15320.80
13	321.80	324.80	15422.70	15264.10	16080.60	15925.30
14	337.00	299.00	14275.90	12194.80	14925.50	12760.60
15	321.20	314.80	14370.70	15048.90	15010.40	15685.30
16	180.40	252.20	11827.10	12547.10	12275.90	13070.90
17	341.40	317.00	11230.30	11874.90	11820.20	12450.90
18	325.60	320.80	11749.30	12550.50	12330.70	13135.60
19	260.80	315.80	13750.70	11255.30	14050.70	11805.60
20	361.00	278.40	10837.70	11175.30	11440.40	11700.60
21	328.40	296.20	10457.30	10594.70	11020.70	11120.90
22	318.40	340.00	10442.70	10433.30	10995.70	11010.50
23	289.20	208.80	11476.20	11917.40	12015.40	12400.80
24	306.80	375.20	14748.90	12856.20	15365.30	13530.40
25	303.60	267.00	15798.60	14683.60	16440.70	15275.90
26	320.00	284.20	15823.60	14825.50	16490.60	15450.80
27	305.20	267.00	11604.50	10048.00	12175.60	10540.90
28	310.00	288.20	13336.60	10297.00	13930.60	10825.80
29	312.40	285.00	12280.80	11122.50	12860.20	11655.30
30	265.00	322.80	10213.40	10408.90	10700.40	10965.60
31	290.00	309.40	11285.00	11329.80	11825.90	11890.70
32	328.00	296.80	9645.40	9708.80	10185.50	10225.80
33	251.80	373.40	9732.40	10293.70	10215.90	10895.70
34	333.60	316.40	10643.70	10160.10	11215.60	10700.40
35	267.20	286.40	11118.70	9464.40	11625.80	9955.90
36	235.40	251.80	11334.60	9058.20	11810.50	9505.60
37	225.60	293.60	10110.60	9339.10	10560.70	9840.80
38	278.20	272.80	9545.00	11809.10	10045.20	12345.40
39	186.60	288.60	11093.80	11102.90	11520.50	11640.80
40	353.40	296.20	10008.90	10107.50	10600.70	10635.50
41	250.60	318.00	10089.00	8922.80	10560.40	9445.60
42	262.40	285.20	8113.80	9787.50	8550.50	10295.90
43	302.00	293.00	10741.70	10255.50	11280.50	10785.60
44	270.40	277.60	12844.90	11413.30	13385.70	11950.80
45	322.80	261.00	13888.50	16172.20	14525.40	16785.60
Range	180.4-430.4	208.8-395.8	8113.8-15823.6	8922.8-16172.2	8550.50-16490.60	9445.60-16785.60
Average	305.08	305.19	12285.10	12142.70	12855.24	12714.73

Table.4 Correlation coefficient (r) between soil properties and forms of K

Parameter	W.S.K	Ex. K	Available K	Non-ex. K	Lattice K	Total K
	(0-15 cm depth)					
pH	0.130	-0.398**	-0.330*	-0.293*	-0.405**	-0.405**
EC	0.141	0.529**	0.574**	0.182	0.528**	0.531**
OC	0.051	-0.006	0.064	-0.096	0.005	0.007
A.N.	0.087	-0.025	0.093	-0.050	-0.029	-0.024
A.P	-0.145	0.234	0.264	0.064	0.201	0.207
	(15-30 cm depth)					
pH	-0.066	-0.043	-0.056	-0.078	-0.019	-0.021
EC	0.041	0.571**	0.588**	0.018	0.570**	0.569**
OC	0.073	-0.092	-0.080	0.111	-0.107	-0.104
A.N.	-0.017	-0.183	-0.190	0.185	-0.194	-0.190
A.P	-0.037	0.115	0.110	-0.152	0.123	0.119

Table value for correlation coefficient (r) at 5% (0.29) and 1% (0.38) for DF 43

Table.5 Inter-relationship among different forms of potassium in soils

Forms of K	Ex.K	Non-ex.K	Lattice K	Total K
	(0-15 cm depth)			
W.S.K	0.043	-0.135	0.021	0.019
Ex.K	-	0.352*	0.991**	0.992**
Non-ex.K	-	-	0.322*	0.347*
Lattice K	-	-	-	0.999**
	(15-30 cm depth)			
W.S.K	0.183	-0.373*	-0.151	-0.155
Ex.K	-	0.183	0.970**	0.970**
Non-ex.K	-	-	0.237	0.253
Lattice K	-	-	-	0.999**

Table value for correlation coefficient at 5% (0.29) and 1% (0.38) for DF 43

The exchangeable K (r=-0.006) and Non-exchangeable K (r=-0.096) showed negative relationship with OC but all the forms of potassium were not reached up to the level of significance. In sub-surface soil samples, coefficient of correlation between organic carbon content and exchangeable, available, lattice and total forms of potassium were showed negative relationship and non-significant. On the other hand, water soluble (r=0.073) and non-exchangeable (r=0.111) forms of potassium showed positive but non-significant relationship with OC in sub-surface soil samples.

Relationship among different soil potassium forms

The results on the relationship of different forms of K are presented in Table 5. Water soluble and exchangeable K were positively related in surface soil (r=0.043) and sub-surface soil (r=0.183). A significant positive relationship between exchangeable K and non-exchangeable K forms (r=0.352*) in surface soil samples but non-significant positive relation was observed in sub surface soil samples (r=0.183). This indicates that the replenishment of exchangeable K upon depletion from non-exchangeable K was easy in these types of black vertisols. Exchangeable K showed a significant positive relation with non-exchangeable K, lattice K and total K in surface and sub-surface soil samples. Similarly, non-exchangeable K also showed a significant positive correlation with lattice K (r=0.322*) and total K (r=0.347*) in surface soil samples, whereas, positive correlation with lattice K (r=0.237) and total K (r=0.253) in sub surface soil samples. A significant positive relationship was obtained between lattice K and total K in surface and sub-surface soil samples (r=0.999**). This indicated the rapid equilibrium between these two forms of soil potassium.

Results of the present study showed that more than 94% part of the available K contributed with exchangeable K. Similarly, more than 95% of the total K was constituted by lattice portion of K. The exchangeable K showed a significant positive relation with non-exchangeable K, lattic K and total K in surface and sub-surface soil samples. A significant positive relationship was obtained between lattice K and total K in both the soil layer.

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