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RESEARCH PAPER

Relationship between potassium forms and selected physico-chemical properties of some intensively vegetable cultivated transitional zone soils of Dharwad district

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Abstract: A study was carried out to determine the distribution of forms of K (water soluble K, exchangeable K, non-exchangeable K, lattice K and total K) of potassium in some intensively vegetable cultivated soils of transitional zone Dharwad district using standard analytical procedure. The soils from three dominant vegetable growing taluka namely Dharwad, Hubballi and Kalaghatagi. Which comprises both black and red soils. The concentrations of total K in soils ranged from 2812.5 to 12222.5 mg kg^{-1}. Kalaghatagi taluka soils showing the lowest (<0.05) value. water soluble K and exchangeable K concentrations in the soils ranged from 1.3 to 12.9 mg kg^{-1} and 121.1 to 267.1 mg kg^{-1} respectively, with the Kalaghatagi taluka soils showing the lowest values (P <0.05) for both K forms. In the study non exchangeable K constituted measured in the soils varied between 300.5 to 1014.5 mg kg^{-1}. The study showed that exchangeable K constituted the highest proportion of the total K measured in the soils, while the proportion of water soluble K in the total K measured was the lowest. Pooling all the data obtained with study, water soluble K, exchangeable K, non-exchangeable K, lattice K and total K concentrations positively corelated with organic carbon, CEC and clay. All the forms of K in soils studied were positively correlated with each other suggested that dynamic equilibrium exists among K forms.

Key words: Exchangeable K, Lattice K, Non-exchangeable K, Organic carbon, Water soluble K

Introduction

Indeed, a significant number of Dharwad district farmers cultivate tomato, brinjal, chilli, potato and bhendi *etc*. These crops are substantial potassium feeders therefore, to know the form of potassium in the transition zone soil is essential as potassium is an important major element in nourishing crop plants. Therefore, to understanding the distribution of potassium forms in some selected soils of transition zone of Dharwad district soils is critical to sustain vegetable crop production. Thus, with the objective to determine the distribution of potassium forms in some selected vegetable growing soils and examine the relationship existing between the potassium forms and physical and chemical properties of the soils the present investigation was carried out.

Material and methods

The surface soils (0 to 20 cm) used for the study were collected from different intensively vegetable growing villages of three talukas of Dharwad district namely Dharwad, Hubballi and Kalaghatagi. In the same location soil sample of adjacent field crops were collected as check sample. The study was conducted in three talukas of Dharwad district with an area of 4,273 sq km (4,27,329 ha) lies in the Northern transition zone of Karnataka state between 15° 48' 003 North latitude and 74° 43' 303 to 75° 33' 253 East longitude. The black cotton soils in the Eastern part having 2.0 to 5.0 meter thickness is high in humus and low in phosphorous and high in available potassium, with normal pH values, the main rock formations in the area are the Gneissic- granites and Schists. Farmers of these taluka pre dominantly growing vegetables *viz.*, tomato, brinjal, chilli, potato and bhendi etc. over a period of fifty to sixty years.

The collected soil samples were air dried under shade, grinded by using wooden pestle and mortar and passed through 2 mm sieve. The sieved samples were stored in plastic covers for further analysis. The Particle size analysis was determined by Hydrometer method (Piper, 2002). Bulk density was determined using Clod method (Black, 1965). Max water holding capacity was determined using Keen's cup method (Sankaran, 1960). Percentage porosity was calculated by the formula (1-BD/PD) x 100. The pH and electrical conductivity of soils were measured using standard analytical procedures as described by Jackson (1973). Organic carbon (OC) was determined using the Walkley-Black method (Jackson, 1973). Available nitrogen (N) was estimated by modified alkaline permanganate method (Sahrawat and Burford, 1982). Available phosphorus was measured using sodium bicarbonate ($NaHCO_3$) as an extractant (Jackson, 1967). Available potassium (K) was determined using the ammonium acetate method (Jackson, 1967). Exchangeable calcium and magnesium were determined EDTA titration method (Black, 1965). Exchangeable sodium and potassium in soils were determined in neutral normal ammonium acetate extract by Flame photometer (Sparks, 1996).

Water soluble K (1:5) (Black, 1965) and 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 available K to get the exchangeable potassium content of the soil. The nonexchangeable K was estimated by boiling 1N 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

Table 1. Physical properties of soils of vegetable and adjacent field crops of selected talukas of Dharwad district

Sl. No.	Village name field crops	Vegetable and ($mg\ m^{-3}$)	BD porosity	Percentage	MWHC class	Textural
				(%)		
			Black soils			
1	Uppin Betageri	Tomato	1.47	55.47	62.77	Clay
		Greengram	1.02	38.49	57.79	Clay
2	Lokur	Tomato	1.29	48.68	54.87	Clay
		Cotton	1.29	48.68	60.00	Clay
3	Govanakoppa	Tomato	1.42	53.58	55.31	Clay
		Soybean	1.51	56.98	61.87	Clay
4	Hebballi	Tomato	1.32	49.81	53.79	Clay
		Groundnut	1.37	51.70	58.82	Clay
5	Karadigudda	Tomato	1.21	48.65	51.28	Clay
		Greengram	1.26	49.95	52.84	Clay
6	Kavalageri	Tomato	1.21	45.66	64.56	Clay
		Greengram	1.23	46.42	59.30	Clay
7	Hangaraki	Chilli	1.32	49.81	52.00	Clay
		Jowar	1.37	51.70	53.14	Clay
8	Kurabagatti	Chilli	1.32	49.81	66.43	Clay
		Chrysanthemum	1.34	50.57	52.56	Clay
9	Maradagi	Chilli	1.28	48.30	60.19	Clay
		Groundnut	1.39	52.45	47.39	Clay
10	Somapur	Chilli	1.29	48.68	57.46	Clay
		Greengram	1.36	51.32	52.52	Clay
11	Pudakalakatti	Chilli	1.27	41.79	49.51	Clay
		Cotton	1.25	46.14	50.81	Clay
12	Marewada	Chilli	1.51	56.98	61.25	Clay
		Greengram	1.52	57.36	58.64	Clay
13	Tadakoda	Chilli	1.34	50.57	64.02	Clay
		Soybean	1.31	49.43	63.64	Clay
14	Agadi	Chilli	1.31	49.43	59.69	Clay
		Groundnut	1.34	50.57	52.27	Clay
15	Shivalli	Brinjal	1.57	59.25	60.05	Clay
		Groundnut	1.58	59.62	62.92	Clay
16	Amminabhavi	Brinjal	1.22	46.04	48.18	Clay
		Groundnut	1.32	49.81	51.85	Sc
17	Timmapur	Brinjal	1.27	47.92	49.75	Clay
		Greengram	1.31	49.43	55.25	Clay
18	Mangalgatti	Brinjal	1.22	46.04	55.72	Scl
		Para grass	1.29	48.68	61.07	Scl
19	Kiresur	Brinjal	1.13	42.64	64.03	Clay
		Blackgram	1.28	48.30	67.84	Clay
20	Sutagatti	Brinjal	1.40	52.83	59.48	Clay
		Sorghum	1.51	56.98	62.34	Clay
21	Kuruvinakoppa	Brinjal	1.53	57.74	63.80	Clay
		Soybean	1.32	49.81	56.69	Clay
22	Managundi	Bhendi	1.28	48.30	49.34	Clay
		Groundnut	1.39	52.45	52.15	Clay
23	Belur	Bhendi	1.40	52.83	57.56	Clay
		Soybean	1.19	44.91	51.54	Clay
24	Halkusugal	Bhendi	1.30	49.06	66.27	Clay
		Blackgram	1.30	49.06	68.50	Clay
25	Hiremagadhur	Bhendi	1.29	48.68	51.16	Clay
		Groundnut	1.36	51.32	58.54	Clay
26	G Basavanakoppa	Bhendi	1.34	50.57	52.04	Clay
		Cotton	1.40	52.83	57.17	Clay
27	Dummawada	Bhendi	1.32	49.81	68.13	Clay
		Soybean	1.34	50.57	63.11	Clay
28	Jodalli	Bhendi	1.42	53.58	56.36	Clay

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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 nonexchangeable K fractions. All the K forms in the extract were determined by flame photometer. Data analysis was performed with SPSS 16 software was used to establish the cross correlation matrix between the various forms of K and the selected physical and chemical soil properties.

Results and discussion

Physical properties of the soils

Selected physical and chemical properties determined in the soils are summarized in Table 1. The texture of black soil varied from clay loam to clay in texture and it varied from sandy clay loam to clay loam in red soils and per centage porosity ranged from 41.8 to 59.3 per cent and the maximum water holding capacity ranged from 48.2 to 68.1 per cent of vegetable growing soils.

Chemical properties of the soils

The pH values varied from neutral to alkaline in reaction (6.90 to 9.20) (Table 2) in black soils. Whereas in red soils ranged from (6.26 to 8.69). The electrical conductivity in both the soil types are well within the permissible limits (< 1.0 dSm^{-1}). The organic carbon content in black soil varied from low to medium (1.90 to 7.00 g kg^{-1}) and in red soil ranged from (3.28 to 6.8 g kg^{-1}). There was no definite trend or relationship was observed between the soil reaction, free $CaCO_3$ with organic carbon content. Free $CaCO_3$ content in black soils ranged from (32.50 to 142.5 g kg^{-1}) and in red soil it ranged from (87.2 to 129.2 g kg^{-1}). Free $CaCO_3$ content which mainly depends on the parent material of the soil developed and pedogenic processes by which the soils have developed. The CEC of black soils ranged from 16.39 to 49.89 cmol (p^+) kg^{-1} and it varied from 31.22 to 45.68 cmol (p^+) kg^{-1} in red soils. The CEC values increased with increasing soil pH value.

		Groundnut	1.51	56.98	57.53	Clay
29	Harobelavadi	Potato	1.38	52.08	53.99	Clay
		Groundnut	1.50	56.60	58.78	Clay
30	Honnapur	Potato	1.53	57.74	59.07	Clay
		Cotton	1.57	59.25	62.39	Clay
31	Kallur	Potato	1.32	49.81	58.86	Clay
		Greengram	1.53	57.74	59.64	Clay
32	Hosetti	Ridgegourd	1.38	52.08	54.47	Clay
		Groundnut	1.50	56.60	58.45	Clay
33	Madanabhavi	Ridgegourd	1.29	48.68	66.40	Clay
		Soybean	1.32	49.81	61.01	Sc
34	Mugali	Beans	1.29	48.68	65.11	Sc
		Groundnut	1.36	51.32	69.50	Clay
35	Mummigatti	French bean	1.31	49.43	56.45	Sc
		Cotton	1.38	52.08	52.02	Sc
36	Kotabagi	Cabbage	1.40	52.83	50.30	Clay
		Greengram	1.58	59.62	60.39	Clay
37	Lakamapur	Cabbage	1.23	46.42	53.77	Clay
		Greengram	1.36	51.32	58.63	Clay
38	Dasanakoppa	Cluster bean	1.40	52.83	56.18	Clay
		Cotton	1.51	56.98	63.34	Clay
39	Garag	Cauli flower	1.22	46.04	64.23	Clay
		Soybean	1.28	48.30	68.88	Clay
40	Jeerigawada	Cluster bean	1.29	48.68	59.93	Clay
		Blackgram	1.24	46.79	60.79	Clay
41	Tadasa	Radish	1.26	47.55	59.65	Clay
		Soybean	1.13	42.64	56.14	Clay
42	Chabbi	Bottle gourd	1.27	47.92	51.67	Clay
		Soybean	1.24	46.79	47.50	Clay
43	Gamanagatti	Radish	1.57	59.25	52.66	Sc
		Soybean	1.51	56.98	74.38	Clay
44	Neeralakatti	Cucumber	1.22	46.04	62.11	Clay
		Greengram	1.28	48.30	75.81	Clay
45	B Gudihal	Bitter gourd	1.40	52.83	61.48	Clay
		Soybean	1.51	56.98	76.56	Clay
Vegetable growing soils						
		Range	1.1-1.6	41.8-59.3	48.2-68.1	
		Average	1.3	50.3	57.8	
		S.D.	0.1	4.0	5.5	
Adjacent field crop soils						
		Range	1.0-1.6	38.5-59.6	47.4-76.6	
		Average	1.4	51.6	59.4	
		S.D.	0.1	4.7	6.9	
46	Narendra	Tomato	1.27	47.92	48.38	Sc
		Soybean	1.34	50.57	52.77	Sc
47	Yadwad	Tomato	1.10	41.50	43.97	Sc
		Greengram	1.16	43.72	48.32	Sc
48	Mulamuttala	Tomato	1.31	49.43	51.85	Sc
		Groundnut	1.34	50.57	53.76	Sc
49	Amaragola	Brinjal	1.30	49.05	58.86	Sc
		Groundnut	1.42	53.58	54.45	Scl
50	Tarihal	Cucumber	1.27	47.92	48.26	Scl
		Sorghum	1.32	49.81	52.12	Scl
Vegetable growing soils						
		Range	1.1-1.3	41.5-49.4	44.0-58.9	
		Average	1.3	47.2	50.3	
		S.D.	0.1	3.2	5.6	
Adjacent field crop soils						
		Range	1.2-1.4	43.7-53.6	48.3-54.5	
		Average	1.3	49.7	52.3	
		S.D.	0.1	3.6	2.4	

Scl : Sandy clay loam, Cl: Clay loam, Sc: Sandy clay, C: Clay

Available nutrient status

The available nitrogen content of soils varied from 84.0 to 460.0 kg ha^{-1} (mean 222.8 kg ha^{-1}). The nitrogen status of majority of the soils falls under low to medium category. The available phosphorus content was low to medium and ranged from 21.2 to 47.1 kg ha^{-1} (mean 36.2 kg ha^{-1}). The available potassium content of are soils of Dharwad district varied from 325.2 to 706.8 kg ha^{-1} (mean of 490.3 kg ha^{-1}), soils are high in available potassium.

Forms of potassium in vegetables and adjacent field crops growing soils

Data showing the concentrations of the various forms of K determined in the soils are presented in (Tables 3 and Table 4).

Water soluble potassium

The water soluble potassium in the vegetable and adjacent field crops cultivated black soils ranged from 1.3 to 11.8 mg kg^{-1} and 2.0 to 12.9 mg kg^{-1} with a mean of 8.2 mg kg^{-1} and 7.7 mg kg^{-1}, (0.11) and (0.11) per cent contribution to total K, respectively. Vegetable and adjacent field crops red soils ranged from 2.4 to 12.8 mg kg^{-1} and 1.6 to 11.2 mg kg^{-1} with a mean of 8.5 mg kg^{-1} and 7.9 mg kg^{-1}, (0.12) and (0.11) per cent contribution to total K, respectively. Better release of K due to addition of FYM and low order removal of K by the crop because of less intensive cropping (Singh and Bansal, 2009).

Exchangeable potassium

The Exchangeable potassium in the vegetable and adjacent field crops cultivated black soils ranged from 121.1 to 261.5 mg kg^{-1} and 117.2 to 267.1 mg kg^{-1} with a mean of 185.7 mg kg^{-1} and 188.2 mg kg^{-1}, (2.62) and (2.68) per cent contribution to total K, respectively. Vegetable and adjacent field crops cultivated red soils ranged from 115.0 to 230.9 mg kg^{-1} and 121.4 to 148.1 mg kg^{-1} with a mean of 151.2 mg kg^{-1} and 133.6 mg kg^{-1}, (2.2) and (1.93) per cent contribution to total K, respectively. Increase in organic matter in soils, the clay humus increases organic matter and clay humus in complex's possibly

Table 2. Chemical properties of soils of vegetable and adjacent field crops of selected talukas of Dharwad district

Sl. No.	Village name	Vegetable and field crops	pH (1:2.5)	EC (1:2.5) (dS m^{-1})	OC ($g\ kg^{-1}$)	Free $CaCO_3$ ($g\ kg^{-1}$)	CEC (cmol (p^+) kg^{-1})
Black soils							
1	Uppin Betageri	Tomato	8.87	0.24	5.37	134.5	40.78
		Greengram	8.81	0.18	5.80	128.5	43.48
2	Lokur	Tomato	8.63	0.17	6.30	35.0	32.71
		Cotton	8.34	0.29	6.19	47.0	37.47
3	Govanakoppa	Tomato	8.57	0.34	5.80	32.5	35.55
		Soybean	8.46	0.20	5.26	65.0	41.61
4	Hebballi	Tomato	8.50	0.40	6.63	139.7	31.36
		Groundnut	8.21	0.10	6.43	121.2	24.51
5	Karadigudda	Tomato	8.21	0.19	6.71	118.6	36.22
		Greengram	8.33	0.18	6.35	129.7	40.50
6	Kavalageri	Tomato	8.71	0.21	3.30	67.5	31.71
		Greengram	8.36	0.12	4.00	45.0	30.16
7	Hangaraki	Chilli	8.82	0.41	6.77	85.0	49.54
		Jowar	8.48	0.10	7.41	55.0	47.57
8	Kurabagatti	Chilli	8.56	0.38	4.80	125.0	39.30
		Chrysanthemum	8.55	0.53	6.40	136.2	44.60
9	Maradagi	Chilli	7.01	0.58	4.40	137.7	44.16
		Groundnut	8.42	0.47	7.20	123.4	41.49
10	Somapur	Chilli	8.61	0.58	6.24	63.7	39.67
		Greengram	7.45	0.24	5.20	55.0	37.56
11	Pudakalakatti	Chilli	7.98	0.22	5.74	89.5	43.43
		Cotton	7.62	0.26	4.69	83.2	48.02
12	Marewada	Chilli	8.53	0.24	2.50	79.7	46.32
		Greengram	8.30	0.12	2.10	81.0	45.29
13	Tadakoda	Chilli	8.36	0.20	6.40	94.7	23.44
		Soybean	8.89	0.26	5.60	96.2	28.75
14	Agadi	Chilli	7.40	0.26	3.70	113.7	31.46
		Groundnut	7.80	0.32	3.50	125.5	23.52
15	Shivalli	Brinjal	8.31	0.58	6.19	95.0	22.38
		Groundnut	8.65	0.43	5.40	67.5	36.75
16	Amminabhavi	Brinjal	7.46	0.40	4.16	131.2	43.34
		Groundnut	8.45	0.38	4.75	123.5	36.24
17	Timmapur	Brinjal	8.02	0.27	4.29	69.7	33.34
		Greengram	8.35	0.15	4.09	63.2	31.52
18	Mangalgatti	Brinjal	8.68	0.29	4.73	127.5	25.87
		Para grass	8.07	0.25	4.90	118.7	31.77
19	Kiresur	Brinjal	8.89	0.58	3.70	139.5	38.83
		Blackgram	8.38	0.65	2.90	84.2	41.52
20	Sutagatti	Brinjal	8.36	0.41	3.10	89.2	28.36
		Sorghum	8.75	0.35	4.40	91.7	31.20
21	Kuruvinakoppa	Brinjal	8.08	0.37	4.20	93.2	35.19
		Soybean	8.37	0.20	3.30	118.7	39.06
22	Managundi	Bhendi	7.50	0.20	6.24	69.2	28.36
		Groundnut	7.82	0.20	5.85	64.6	46.35
23	Belur	Bhendi	7.86	0.45	6.30	76.2	48.63
		Soybean	7.32	0.19	6.56	83.7	43.45
24	Halkusugal	Bhendi	9.20	0.42	6.70	139.2	41.82
		Blackgram	8.43	0.78	6.90	134.5	44.37
25	Hiremagadhur	Bhendi	8.24	0.41	5.80	56.0	43.68
		Groundnut	8.38	0.82	5.60	51.2	46.02
26	G Basavanakoppa	Bhendi	8.03	0.29	5.70	69.2	28.99
		Cotton	7.80	0.34	5.32	65.0	30.45
27	Dummawada	Bhendi	8.18	0.44	4.30	138.2	47.45
		Soybean	8.00	0.58	4.40	132.7	41.35
28	Jodalli	Bhendi	8.21	0.12	5.40	109.2	49.89
		Groundnut	8.14	0.27	5.00	113.7	43.54

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29	Harobelavadi	Potato	8.26	0.27	6.90	142.5	45.56
		Groundnut	8.32	0.20	6.36	128.7	47.40
30	Honnapur	Potato	8.23	0.24	4.58	128.5	38.52
		Cotton	8.25	0.14	4.19	113.2	34.62
31	Kallur	Potato	8.77	0.46	1.90	132.5	34.76
		Greengram	8.81	0.30	2.30	126.2	39.75
32	Lakamapur	Cabbage	8.33	0.22	5.30	118.7	43.16
		Greengram	8.18	0.14	5.60	128.7	38.58
33	Mummigatti	French bean	8.12	0.15	3.10	77.5	25.49
		Cotton	8.23	0.24	3.75	81.2	27.00
34	Dasanakoppa	Cluster bean	8.32	0.15	5.85	133.7	41.98
		Cotton	8.45	0.15	5.20	126.2	44.48
35	Garag	Cauli flower	8.40	0.32	2.90	131.2	44.94
		Soybean	8.73	0.15	3.90	121.0	42.74
36	Madanabhavi	Ridgegourd	6.90	0.15	6.30	62.5	31.28
		Soybean	8.38	0.18	6.80	72.5	33.21
37	Mugali	Beans	7.76	0.18	5.60	73.2	36.51
		Groundnut	8.30	0.28	5.43	79.6	45.84
38	Hosetti	Ridgegourd	7.36	0.13	5.40	117.5	39.68
		Groundnut	6.95	0.17	5.80	125.0	37.67
39	Kotabagi	Cabbage	8.32	0.23	7.00	137.5	46.03
		Greengram	8.92	0.25	7.40	128.5	40.95
40	Jeerigawada	Cluster bean	7.92	0.22	6.90	123.7	38.10
		Blackgram	8.31	0.14	6.50	148.7	36.47
41	Neeralakatti	Cucumber	8.25	0.16	4.90	116.2	16.39
		Greengram	8.32	0.21	4.29	101.2	28.07
42	B Gudihal	Bitter gourd	6.98	0.16	3.90	129.0	23.37
		Soybean	7.18	0.18	4.70	132.2	24.28
43	Tadasa	Radish	7.84	0.36	2.90	69.2	28.74
		Soybean	7.98	0.32	2.30	65.0	27.39
44	Chabbi	Bottle gourd	8.44	0.38	4.00	127.5	39.74
		Soybean	8.21	0.43	3.50	105.0	38.06
45	Gamanagatti	Radish	8.40	0.53	5.70	131.2	34.49
		Soybean	7.59	0.61	4.92	136.2	38.51
Vegetable growing soils							
		Range	6.9-9.2	0.1-0.6	1.9-7.0	32.5-42.5	16.4-49.9
		Average	8.2	0.3	5.1	103.8	36.7
		S.D.	0.5	0.1	1.4	31.4	8.1
Adjacent field crop soils							
		Range	7.0-8.9	0.1-0.8	2.1-7.4	45.0-148.7	23.5-48.0
		Average	8.2	0.3	5.1	100.5	37.8
		S.D.	0.4	0.2	1.4	30.3	6.9
				Red soils			
46	Narendra	Tomato	7.78	0.15	5.60	87.2	39.28
		Soybean	7.18	0.24	4.84	84.0	38.00
47	Yadwad	Tomato	6.26	0.32	4.60	90.0	43.15
		Greengram	6.66	0.29	3.90	66.0	34.63
48	Mulamuttala	Tomato	8.69	0.19	6.00	85.3	38.59
		Groundnut	7.26	0.31	6.60	86.7	41.42
49	Amaragola	Brinjal	7.40	0.35	3.28	97.2	45.68
		Groundnut	7.48	0.37	3.50	94.7	46.57
50	Tarihal	Cucumber	7.46	0.21	6.80	87.2	31.22
		Sorghum	7.49	0.24	6.20	98.0	29.71
Vegetable growing soils							
		Range	6.2-8.7	0.1-0.4	3.3-6.8	85.3-97.2	31.2-45.7
		Average	7.5	0.2	5.3	89.4	39.6
		S.D.	0.9	0.1	1.4	4.7	5.5
Adjacent field crop soils							
		Range	6.7-7.5	0.2-0.4	3.5-6.6	66.0-98.0	29.7-46.6
		Average	7.2	0.3	5.0	85.9	38.1
		S.D.	0.3	0.1	1.4	12.5	6.4

preceded more exchange sites and access to K (Joshi *et al.,* 1978, Sharma *et al*., 2009).

Non-exchangeable potassium

The Non exchangeable potassium in the vegetable and adjacent field crops cultivated black soils ranged from 300.5 to 1014.5 mg kg^{-1} and 314.8 to 945.8 mg kg^{-1} with a mean of 575.0 mg kg^{-1} and 611.7 mg kg^{-1}, (8.13) and (8.7) per cent contribution to total K, respectively. Vegetable and adjacent field crops cultivated red soils ranged from 357.5 to 647.7 mg kg^{-1} and 268.9 to 658.6 mg kg^{-1} with a mean of 537.8 mg kg^{-1} and 478.1 mg kg^{-1}, (8.02) and (6.96) per cent contribution to total K, respectively. Removal of K then input, and soils having lower amount of silt plus clay contents (Choudhary and Pareek, 1976). It has been seen that most soils formed on basement of complex materials and alluvial sediments contains some amount of weathered mica and thus high values of fixed K reserve (Al- Zubaidi *et al*., 2008).

Lattice potassium

The lattice potassium in in the vegetable and adjacent field crops cultivated black soils ranged from 2787.5 to 11449.1 mg kg^{-1} and 2209.9 to 10188.0 mg kg^{-1} with a mean of 6303.6 mg kg^{-1} and 6191.7 mg kg^{-1}, (89.1) and (88.5) per cent contribution to total K, respectively. Vegetable and adjacent field crops cultivated red

Table 3. Forms of potassium in black soils of vegetable and adjacent field crops of selected talukas of Dharwad district

Sl. No.	Village name	Vegetable and field crops	Water soluble-K	Ex-K	Non-ex K	Lattice-K K(%)	Lattice-K	Total-K (%)	Total-K
			(mg kg^{-1})					(mg kg^{-1})	
1	Uppin Betageri	Tomato	9.1(0.1)	192.6(2.1)	984.0(10.6)	8126.9(87.3)	0.8127	9312.5	0.9313
		Greengram	8.2(0.1)	202.9(2.0)	819.8(8.3)	8876.7(89.6)	0.8877	9907.5	0.9908
2	Hangaraki	Chilli	10.4(0.2)	145.5(2.3)	404.5(6.3)	5847.1(91.3)	0.5847	6407.5	0.6408
		Jowar	5.0(0.1)	124.3(3.2)	474.4(12.1)	3306.4(84.6)	0.3306	3910.0	0.3910
3	Lokur	Tomato	11.1(0.2)	198.7(4.2)	430.7(9.1)	4077.1(86.4)	0.4077	4717.5	0.4718
		Cotton	6.2(0.1)	189.2(3.1)	599.0(9.8)	5295.6(87.0)	0.5296	6090.0	0.6090
4	Garag	Cauli flower	10.2(0.1)	180.9(2.5)	555.8(7.6)	6543.2(89.8)	0.6543	7290.0	0.7290
		Soybean	12.7(0.2)	229.1(3.0)	590.2(7.8)	6705.5(89.0)	0.6706	7537.5	0.7538
5	Kurabagatti	Chilli	11.8(0.1)	214.9(2.3)	638.9(6.8)	8464.4(90.7)	0.8464	9330.0	0.9330
		Chrysanthemum	10.9(0.1)	228.3(2.4)	787.6(8.2)	8563.2(89.3)	0.8563	9590.0	0.9590
6	Maradagi	Chilli	9.5(0.1)	132.3(1.2)	927.4(8.1)	10343.3(90.6)	1.0343	11412.5	1.1413
		Groundnut	7.9(0.1)	139.5(1.3)	865.5(8.2)	9599.7(90.5)	0.9600	10612.5	1.0613
7	Shivalli	Brinjal	11.6(0.1)	180.8(1.8)	936.8(9.5)	8683.3(88.5)	0.8683	9812.5	0.9813
		Groundnut	10.4(0.1)	186.3(1.6)	915.4(8.1)	10188.0(90.2)	1.0188	11300.0	1.1300
8	Somapur	Chilli	2.5(0.0)	236.6(2.0)	429.4(3.5)	11449.1(94.5)	1.1449	12117.5	1.2118
		Greengram	3.5(0.1)	240.1(3.5)	468.8(6.7)	6245.1(89.8)	0.6245	6957.5	0.6958
9	Amminabhavi	Brinjal	6.5(0.1)	155.8(1.8)	737.7(8.6)	7670.0(89.5)	0.7670	8570.0	0.8570
		Groundnut	8.5(0.1)	154.9(1.5)	787.8(7.8)	9118.8(90.6)	0.9119	10070.0	1.0070
10	Govanakoppa	Tomato	10.0(0.1)	224.3 (2.1)	858.5(8.1)	9459.7 (89.6)	0.9460	10552.5	1.0553
		Soybean	11.0(0.1)	218.3 (2.9)	668.4(9.0)	6537.4 (87.9)	0.6537	7435.0	0.7435
11	Managundi	Bhendi	7.3(0.1)	154.7(1.3)	1014.5(8.3)	11046.1(90.4)	1.1046	12222.5	1.2223
		Groundnut	6.8(0.1)	173.1(2.0)	581.8(6.6)	8058.4 (91.4)	0.8058	8820.0	0.8820
12	Hebballi	Tomato	9.6(0.1)	188.0 (2.7)	730.9 (10.3)	6151.6 (86.9)	0.6152	7080.0	0.7080
		Groundnut	6.3(0.1)	182.1 (2.3)	806.5 (10.2)	6890.2 (87.4)	0.6890	7885.0	0.7885
13	Harobelavadi	Potato	9.0(0.2)	171.2 (4.4)	303.8(7.8)	3423.5 (87.6)	0.3424	3907.5	0.3908
		Groundnut	7.2(0.3)	228.6(8.1)	373.9(13.3)	2202.9(78.3)	0.2203	2812.5	0.2813
14	Honnapur	Potato	8.4(0.2)	180.1(3.8)	482.8(10.2)	4068.8(85.8)	0.4069	4740.0	0.4740
		Cotton	11.2(0.2)	201.0(3.5)	550.7(9.7)	4922.2(86.6)	0.4922	5685.0	0.5685
15	Mummigatti	French bean	11.0(0.1)	232.5(2.7)	627.8(7.3)	7691.3(89.8)	0.7691	8562.5	0.8563
		Cotton	10.0(0.1)	258.6(2.9)	788.6(8.7)	8000.3(88.3)	0.8000	9057.5	0.9058
16	Lakamapur	Cabbage	5.6(0.1)	261.5(4.0)	465.0(7.1)	5820.5(88.8)	0.5821	6552.5	0.6553
		Greengram	7.5(0.1)	206.3(3.0)	561.1(8.0)	6197.7(88.9)	0.6198	6972.5	0.6973
17	Timmapur	Brinjal	1.6(0.0)	127.2(2.6)	471.3(9.7)	4245.0(87.6)	0.4245	4845.0	0.4845
		Greengram	2.3(0.0)	137.9(3.0)	353.8(7.6)	4141.0(89.3)	0.4141	4635.0	0.4635
18	Karadigudda	Tomato	5.2(0.1)	184.4(3.8)	451.5(9.4)	4184.9(86.7)	0.4185	4826.0	0.4826
		Greengram	5.6(0.1)	187.5(4.1)	487.1(10.7)	3879.8(85.1)	0.3880	4560.0	0.4560
19	Pudakalakatti	Chilli	4.8(0.1)	204.6(6.1)	345.6(10.3)	2787.5(83.4)	0.2788	3342.0	0.3342
		Cotton	4.2(0.1)	210.8(6.2)	391.2(11.5)	2790.8(82.2)	0.2791	3397.0	0.3397
20	Dasanakoppa	Cluster bean	8.7(0.2)	155.1(3.0)	325.5(6.2)	4728.3(90.6)	0.4728	5217.5	0.5218
		Cotton	7.4(0.2)	205.0(5.3)	441.7(11.4)	3206.0(83.1)	0.3206	3860.0	0.3860
21	Kavalageri	Tomato	11.5(0.3)	216.7(5.3)	301.5(7.4)	3527.9(86.9)	0.3528	4057.5	0.4058
		Greengram	11.3(0.2)	218.3(4.7)	331.3(7.2)	4056.7(87.9)	0.4057	4617.5	0.4618

Contd....

22	Marewada	Chilli	6.3(0.1)	229.1(3.8)	356.3(5.9)	5453.4(90.2)	0.5453	6045.0	0.6045
		Greengram	8.8(0.1)	206.9(2.9)	314.8(4.3)	6707.1(92.7)	0.6707	7237.5	0.7238
23	Jeerigawada	Cluster bean	7.3(0.2)	134.7(3.0)	300.5(6.7)	4012.6(90.1)	0.4013	4455.0	0.4455
		Blackgram	6.6(0.1)	132.6(2.2)	600.5(9.7)	5422.9(88.0)	0.5423	6162.5	0.6163
24	Neeralakatti	Cucumber	11.2(0.1)	184.9(2.1)	532.8(6.0)	8133.7(91.8)	0.8134	8862.5	0.8863
		Greengram	5.7(0.1)	171.2(1.8)	598.0(6.4)	8545.2(91.7)	0.8545	9320.0	0.9320
25	Kallur	Potato	8.6(0.1)	165.0(2.3)	504.9(7.1)	6386.6(90.4)	0.6387	7065.0	0.7065
		Greengram	8.9(0.2)	206.9(3.5)	376.3(6.4)	5303.0(90.0)	0.5303	5895.0	0.5895
26	Hosetti	Ridgegourd	7.7(0.1)	141.7(2.1)	562.7(8.3)	6100.5(89.5)	0.6101	6812.5	0.6813
		Groundnut	9.1(0.1)	152.0(2.4)	464.2(7.3)	5717.3(90.1)	0.5717	6342.5	0.6343
27	Madanabhavi	Ridgegourd	6.3(0.1)	121.1(1.7)	360.3(5.0)	6697.4(93.2)	0.6697	7185.0	0.7185
		Soybean	6.6(0.1)	135.4(1.5)	878.1(9.7)	8042.5(88.7)	0.8043	9062.5	0.9063
28	Mugali	Beans	11.4(0.1)	148.9(1.8)	574.1(7.1)	7400.6(91.0)	0.7401	8135.0	0.8135
		Groundnut	12.9(0.3)	152.4(3.1)	337.6(6.9)	4417.289.8	0.4417	4920.0	0.4920
29	Tadakoda	Chilli	10.7(0.2)	167.1(2.7)	437.1(7.0)	5597.7(90.1)	0.5598	6212.5	0.6213
		Soybean	5.5(0.1)	197.7(2.8)	485.2(6.8)	6401.6(90.3)	0.6402	7090.0	0.7090
30	Kotabagi	Cabbage	10.9(0.3)	131.8(3.5)	303.4(8.0)	3361.5(88.3)	0.3362	3807.5	0.3808
		Greengram	10.5(0.2)	131.7(2.9)	349.8(7.8)	4003.0(89.1)	0.4003	4495.0	0.4495
31	Belur	Bhendi	8.4(0.2)	244.3(6.7)	399.4(11.0)	2993.0(82.1)	0.2993	3645.0	0.3645
		Soybean	8.5(0.2)	117.2(3.0)	383.6(9.7)	3463.3(87.2)	0.3463	3972.5	0.3973
32	Mangalgatti	Brinjal	8.0(0.2)	142.9(3.3)	336.7(7.8)	3832.4(88.7)	0.3832	4320.0	0.4320
		Para grass	5.6(0.2)	158.7(4.4)	387.0(10.8)	3028.8(84.6)	0.3029	3580.0	0.3580
33	Kiresur	Brinjal	1.3(0.0)	231.4(3.2)	845.4(11.8)	6062.0(84.9)	0.6062	7140.0	0.7140
		Blackgram	2.5(0.0)	240.1(3.2)	945.8(12.7)	6256.6(84.0)	0.6257	7445.0	0.7445
34	Halkusugal	Bhendi	8.3(0.1)	247.0(3.0)	590.0(7.2)	7394.8(89.7)	0.7395	8240.0	0.8240
		Blackgram	6.2(0.1)	263.2(2.8)	915.9(9.9)	8059.8(87.2)	0.8060	9245.0	0.9245
35	Tadasa	Radish	9.7(0.1)	225.2(3.1)	645.6(8.9)	6364.6(87.8)	0.6365	7245.0	0.7245
		Soybean	9.0(0.1)	213.4(3.4)	901.2(14.2)	5206.4(82.2)	0.5206	6330.0	0.6330
36	Chabbi	Bottle gourd	5.4(0.1)	187.8(2.6)	739.6(10.2)	6284.7(87.1)	0.6285	7217.5	0.7218
		Soybean	9.8(0.1)	169.8(1.8)	836.1(8.6)	8684.4(89.5)	0.8684	9700.0	0.9700
37	Hiremagadhur	Bhendi	9.6(0.1)	245.6(2.4)	857.7(8.3)	9267.2(89.3)	0.9267	10380.0	1.0380
		Groundnut	2.0(0.0)	267.1(3.4)	671.8(8.6)	6879.2(88.0)	0.6879	7820.0	0.7820
38	Gamanagatti	Radish	8.5(0.2)	252.7(5.7)	330.8(7.4)	3868.0(86.7)	0.3868	4460.0	0.4460
		Soybean	9.2(0.1)	130.1(1.8)	635.5(8.9)	6372.7(89.2)	0.6373	7147.5	0.7148
39	Sutagatti	Brinjal	5.9(0.1)	151.9(1.7)	896.6(10.1)	7798.1(88.1)	0.7798	8852.5	0.8853
		Sorghum	7.5(0.1)	159.3(2.0)	686.1(8.7)	7027.2(89.2)	0.7027	7880.0	0.7880
40	Agadi	Chilli	9.7(0.1)	237.2(2.6)	695.6(7.6)	8257.6(89.8)	0.8258	9200.0	0.9200
		Groundnut	9.4(0.1)	222.5(2.3)	782.5(8.0)	8785.6(89.6)	0.8786	9800.0	0.9800
41	G Basavanakoppa	Bhendi	11.5(0.1)	192.6(1.8)	920.4(8.6)	9588.1(89.5)	0.9588	10712.5	1.0713
		Cotton	10.9(0.1)	212.4(1.9)	908.7(8.2)	9995.5(89.8)	0.9996	11127.5	1.1128
42	Kuruvinakoppa	Brinjal	8.9(0.2)	150.1(3.2)	369.9(7.9)	4146.2(88.7)	0.4146	4675.0	0.4675
		Soybean	7.0(0.1)	222.8(4.3)	502.6(9.6)	4485.1(86.0)	0.4485	5217.5	0.5218
43	Dummawada	Bhendi	10.9(0.3)	163.6(4.5)	565.2(15.5)	2900.4(79.7)	0.2900	3640.0	0.3640
		Soybean	11.7(0.3)	156.0(3.7)	640.7(15.2)	3409.1(80.8)	0.3409	4217.5	0.4218
44	Jodalli	Bhendi	5.0(0.1)	182.8(2.4)	718.3(9.6)	6589.0(87.9)	0.6589	7495.0	0.7495
		Groundnut	7.1(0.1)	180.3(2.5)	680.7(9.5)	6292.0(87.9)	0.6292	7160.0	0.7160
45	B Gudihal	Bitter gourd	3.7(0.0)	136.8(1.8)	608.0(8.0)	6831.6(90.1)	0.6832	7580.0	0.7580
		Soybean	3.1(0.0)	148.1(1.8)	601.2(7.4)	7337.6(90.7)	0.7338	8090.0	0.8090
Vegetable growing soils									
	Range		1.3-11.8	121.1-261.5	300.5-1014.5	2787.5-11449.1	0.3-1.1	3342.0-12222.5	0.3-1.2
	Average		8.2 (0.11)	185.7 (2.62)	575.0 (8.13)	6303.6 (89.1)	0.6	7072.4	0.7
	S.D.		2.8	39.8	215.2	2281.8	0.2	2451.2	0.2
Adjacent field crops									
	Range		2.0-12.9	117.2-267.1	314.8-945.8	2202.9-10188.0	0.2-1.0	2812.5-11300.0	0.3-1.1
	Average		7.7 (0.11)	188.2 (2.68)	611.7 (8.7)	6191.7 (88.5)	0.6	6999.3	0.7
	S.D.	2.8	40.0	194.1	2127.6	0.2	2284.4	0.2	

Figures in parentheses indicates percentage contribution of different forms of potassium towards total potassium

Table 4. Forms of potassium in red soils of vegetable growing fields and adjacent field crops of selected talukas of Dharwad district

Sl. No.	Village name	Vegetable and field crops	WS-K	Ex-K	Non-ex-K	Lattice-K	Lattice (%)	Total-K	Total-K (%)
			(mg kg^{-1})					(mg kg^{-1})	
1	Narendra	Tomato	6.1(0.1)	119.1(1.7)	647.7(9.1)	6317.2(89.1)	0.6317	7090.0	0.7090
		Soybean	6.3(0.1)	148.1(1.8)	495.7(6.0)	7545.0(92.1)	0.7545	8195.0	0.8195
2	Yadwad	Tomato	12.8(0.4)	115.0(3.5)	357.5(10.8)	2827.3(85.4)	0.2827	3312.5	0.3313
		Greengram	11.2(0.4)	127.6(4.5)	268.9(9.6)	2404.9(85.5)	0.2405	2812.5	0.2813
3	Mulamuttala	Tomato	11.0(0.2)	133.5(1.9)	472.7(6.7)	6472.8(91.3)	0.6473	7090.0	0.7090
		Groundnut	10.0(0.1)	121.4(1.5)	541.0(6.7)	7357.6(91.6)	0.7358	8030.0	0.8030
4	Amaragola	Brinjal	2.4(0.0)	230.9(2.6)	615.2(6.9)	8064.1(90.5)	0.8064	8912.5	0.8913
		Groundnut	1.6(0.0)	143.9(1.5)	658.6(6.8)	8941.0(91.7)	0.8941	9745.0	0.9745
5	Tarihal	Cocumber	10.3(0.1)	157.7(2.2)	595.7(8.4)	6353.9(89.3)	0.6354	7117.5	0.7118
		Sorghum	10.5(0.2)	127.1(2.2)	426.5(7.5)	5126.0(90.1)	0.5126	5690.0	0.5690
Vegetable growing soils									
Range			2.4-12.8	115.0-230.9	357.5-647.7	2827.3-8064.1	0.3-0.8	3312.5-8912.5	0.3-0.9
Average			8.5 (0.12)	151.2 (2.2)	537.8 (8.02)	6007.1 (89.5)	0.6 0.2	6704.5 2052.4	0.7 0.2
S.D.			4.2	47.6	120.6	1922.0			
Adjacent field crops									
Range			1.6-11.2	121.4-148.1	268.9-658.6	2404.9-8941.0	0.2-0.9	2812.5-9745.0	0.3-1.0
Average			7.9 (0.11)	133.6 (1.93)	478.1 (6.96)	6274.9 (91.0)	0.6	6894.5	0.7
S.D.			4.0	11.7	144.3	2558.8	0.3	2702.8	0.3

Figures in parentheses indicates percentage contribution of different forms of potassium towards total potassium

soils ranged from 2827.3 to 8064.1 mg kg^{-1} and 2404.9 to 8941.0 mg kg^{-1} with a mean of 6007.1 mg kg^{-1} and 6274.9 mg kg^{-1}, (89.5) and (91.0) per cent contribution to total K, respectively. Some K absorbed on the edges of inner side of lattice K, and which could not be replaced by exchangeable NH_4^+ but could be extracted with HCL which is slowly exchangeable (Ghosh and Bhattacharyya, 1982) lowest (268.9 mg kg^{-1}) amount of lattice K were found at Dharwad taluka possibly low amount of silt plus clay content in the soils (Joshi *et al*., 1978).

Total potassium

The total potassium in the vegetable and adjacent field crops cultivated black soils ranged from 3342.0 to 12222.5 mg kg^{-1} and 2812.5 to 11300.0 mg kg^{-1} with a mean of 7072.4 mg kg^{-1} and 6999.3 mg kg^{-1}, respectively. Vegetable and adjacent field crops cultivated red soils ranged from 3312.5 to 8912.5 mg kg^{-1} and 2812.5 to 9745.0 mg kg^{-1} with a mean of 6704.5 mg kg^{-1} and 6894.5 mg kg^{-1}, respectively. The degree of weathering is important for total content of potassium in soil. Depending on clay mineralogy, lattice-K content and organic matter content, the total K. The results are in comparison with those of research findings of Hebsur and Gali (2011), Jagmohan and Grewal (2014).

Relationship between forms of potassium and selected soil properties

Results of simple correlation analysis between different forms of K and the various soil chemical properties are given in Table 5 and Table 6.

In vegetable growing soils water soluble, exchangeable, non exchangeable, lattice, total and available-K showed positive relationship with silt and clay and significant positive correlation organic carbon (r = 0.134**, r = 0.050**, r = 0.59**, r = 0.057**, respectively). among different forms of potassium water soluble, lattice and total-K showed positive correlation with CEC (r = 0.065*, r = 0.085*, r = 0.203*, r = 0.226*, r = 226*, r = 227*,

Table 5. Correlation between different forms of soil K and soil properties in vegetable and adjacent field crop soils of selected talukas of Dharwad district

Parameters	pH	EC	OC	$CaCO_3$	CEC	Sand	Silt	Clay
Water soluble-K	0.036	0.009	0.095*	-0.046	0.065*	0.177*	0.231*	0.020*
Exchangeable-K	0.335	0.136	0.134**	-0.031	0.085*	-0.304	0.116	0.239*
Non-Exchangeable-K	-0.064	0.254	0.050**	-0.118	0.203*	-0.147	0.040	0.138*
Lattice-K	-0.051	0.120	0.059**	-0.026	0.226*	-0.156	0.011	0.168*
Total-K	-0.059	0.136	0.057**	-0.014	0.227*	-0.164	0.016	0.173*

** Significant at 0.01 level * Significant at 0.05 level

Table 6. Correlation among forms of soil K in vegetable and adjacent field crops of selected talukas of Dharwad district

Parameters	Water soluble-K	Exchangeable-K	Non exchangeable-K	Lattice-K	Total-K
Water soluble-K	1	0.054**	0.067**	0.078**	0.078**
Exchangeable-K	-	1	0.211**	0.190**	0.213**
Non-Exchangeable-K	-	-	1	0.731**	0.771**
Lattice-K	-	-	-	1	0.998**
Total-K	-	-	-	-	1

** Significant at 0.01 level * Significant at 0.05 level

respectively), all the forms of K are negatively corelated with sand, pH and $CaCO_3$. Correlation among the forms of potassium in vegetable and adjacent field crops growing soils all the forms of K were positively correlated with each other Total-K was positively and significantly correlated with WSK (r = 0.078**), Ex-K (r = 0.213**), non exchangeable-K (r = 0.771**) and lattice-K (r = 0.998**). Lattice-K was positively and significantly correlated with WSK (r = 0.078**), Ex-K (r = 0.190**) and non exchangeable-K (r = 0.731**). Non exchangeable-K was positively and significantly correlated with WSK (r = 0.067**) and Ex-K (r = 0.211**). Ex-K was positively and significantly correlated with WSK (r = 0.054**). These results are in accordance with Kundu *et al.* (2014), Panwar, (2016) and Mondal and Ramkala, (2017).

Conclusion

Percentage contribution of different forms water soluble K (0.1 to 0.12 per cent), exchangeable K (2 to 3 per cent), non exchangeable K (8 to 10 per cent) and lattice K (89 to 90 per cent) of K towards total potassium based on K index value > 2.0 mg kg^{-1} which suffices K concentration in the soils range from 50 to 150 mg kg^{-1} which helps K fertilization for long periods. Soil fertility categorization studies based on exchangeable K and non-exchangeable- K in all soils sample indicate the soils are high in (exchangeable K > 120 mg kg^{-1}) and (Non-exchangeable- K > 600 mg kg^{-1}), the values indicating the soils are rich in K which doesn't need any additional K fertilization. The study also demonstrated that water soluble and exchangeable K concentrations in the soils were positively influenced by increasing organic carbon content and maximum water holding capacity, and sand, free $CaCO_3$ and soil pH negatively affected the K availability. A highly significant and positive relationship was observed between forms of K. These relationships indicate that there existed equilibrium among different forms of K and depletion of one is instantly replenished by one or more of the other forms of K.

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