Journal of Pharmacognosy and Phytochemistry 2017; 6(6): 1204-1207

Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2017; 6(6): 1204-1207
Received: 27-09-2017
Accepted: 28-10-2017

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Potassium dynamics in surface layer of maize growing red soil type of Haveri district, Karnataka, India

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Abstract
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. These forms such as water soluble, exchangeable, non-exchangeable and lattice potassium were studied in twenty representative randomly collected maize growing soils of Haveri district, Karnataka, India. The soils varied appreciably in their physico-chemical properties depending on nature and amount of parent material. The available potassium in red soils varied from 268.80 to 483.84 kg ha^{-1}. The available potassium was medium to high in status. The variation in K status was due to cultural practices, application of fertilizers, organic manures and other inputs. 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}. The reason for this was due to addition of water soluble potash fertilizers at surface zone. The exchangeable potassium content of red soils ranged from 44.80 to 78.40 mg kg^{-1} in surface layer. The exchangeable potassium in surface layer was high because of high exchange sites offered for K fertilization and also addition of organic manures which might have enhanced the exchangeable K in solution phase. The non-exchangeable potassium of red soils ranged from 495.88 to 653.66 mg kg^{-1} in surface. The increase in non-exchangeable potassium was due to adsorption and fixation of K removed from surface through leaching. The lattice potassium of red soils varied from 0.92 to 1.28 per cent. The total potassium in surface depth of red soils varied from 0.97 to 1.35 per cent. Based on degree of weathering and amount of fertilizer that has been applied, the various forms of potassium varied among the samples.

Keywords: Potassium dynamics, red soil, lattice potassium

1. Introduction
Potassium is the most abundant cation in plant cells and is the second most abundant nutrient after nitrogen in leaves. Potassium is thus more abundant than phosphorus (Sardans *et al.*, 2012). Potassium represents 2.6 per cent of the weight of the Earth's crust. However, terrestrial ecosystems such as forests and shrublands, have a great biological capacity for retention of potassium by several processes, such as plant 'pumping' and resorption of K (Nowak *et al.*, 1991 and Jobbágy and Jackson, 2001). Potassium 'pumping' describes the uptake of K by plants from deep soil layers (with K provided in part by mineral weathering release) to upper soil layers. The potential of parent material together with a conservative bio-geochemical cycle underlie maintenance of the supply of K to plants (Nowak *et al.*, 1991 and Jobbágy and Jackson, 2001). 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. Maize is grown in temperature between 18°C and 27°C during the day and around 14°C during the night. Maize is grown mostly in regions having annual rainfall between 60 and 110 cm. But it is also grown in areas having rainfall of about 40 cm. Maize grows on a wide range of soils, ranging from temperate podzols to the leached red soils of the tropics. But, the best suitable soil for maize is deep, rich soils of the sub-tropics, where there is abundant nitrogen and potassium. Karnataka accounts for 6 per cent area and 12 per cent of production share. The area under maize in Northern Karnataka is 52 per cent. The area under maize in Haveri district is 1,48,204 ha, with a production of 4,56,842 tonnes with an average productivity of 3,460 kg ha^{-1} (Anon., 2015) [1]. The adoption of hybrid maize varieties, exhaustive nature of the crop, new cultural practices and their interrelationships with nutrient supply have resulted in the application of ever increasing amounts of fertilizers in Karnataka. 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 on K dynamics under maize cropping system of red soil type was studied.

2. Material and Methods

The surface samples of depth 0-20 cm were collected based on predominance of soil type (red) and dominance of cropped area under maize of Haveri district and studied during 2016-17 at UAS, Dharwad. The net cultivated area of the district is 17,488 ha (Anon., 2015) [1]. The annual rainfall of the region is 792.70 mm (Anon., 2015) [1]. The study location lies between the coordinates of 14˚ N to 75˚ E. The soil samples collected 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. Soil reaction was determined in 1:2.5 soil water suspension after stirring for 30 minutes using a pH meter (Jackson, 1973) [6]. It was determined in 1:2.5 soil: water suspension after obtaining supernatant as described by Jackson (1973) [6] using conductivity meter. Organic carbon was determined by Walkley and Black's wet oxidation method as described by Piper (1996) [13]. The per cent distribution of particles of different size *viz.,* sand, silt and clay was determined by mechanical analysis using Bouyoucos Hydrometer method (Jackson, 1973) [6]. Soils (50 g) were shaken with 100 ml of 5 per cent solution of sodium hexa meta phosphate. Later, per cent silt and clay was estimated by hydrometer and per cent sand was calculated by subtracting silt and clay from 100. The exchangeable calcium and magnesium were determined in the neutral normal ammonium acetate the aliquot of the extract was titrated against standard versenate solution and sodium and potassium were determined by flame photometry (Jackson, 1973) [6]. Available potassium was determined by extracting soil with neutral normal ammonium acetate and the contents of K in solution and was estimated by flame photometery (Jackson, 1973) [6].

Different forms of potassium was estimated by.

2.1. 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) [3]. The potassium in the extract was determined by flame photometer.

2.2. Exchangeable potassium

Exchangeable potassium was determined by extracting with *N N* NH_4OAc solution as outlined by Knudsen *et al*. (1982) [9]. 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 100ml 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.

2.3. Non exchangeable potassium

The boiling 1*N* HNO_3 method as outlined by Knudsen *et al*. (1982) [9] 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.

2.4. Total potassium

Total potassium content was determined by digesting the samples with hydrofluoric acid in a closed vessel (Lim and Jackson, 1982) [12]. 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.

2.5. Lattice potassium

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

3. Results and Discussion

The available potassium in red soils varied from 268.80 to 483.84 kg ha^{-1} in surface layer with a mean of 339.53 kg ha^{-1}. The available potassium in red soils was medium to high in status. The highest available potassium was recorded in Guttal soil and that of lowest in Aremallapur-4 soil. The variation in K status might be due to cultural practices, application of fertilizers, organic manures and other inputs. The higher values for available potassium was due to the fact that application of water soluble potassium fertilizers and also high exchange sites offered for potassium at surface layer. Similar results were obtained by Yadav *et al.* (1991) [15], Upadhyay and Bhandari (1997) [14] and Jagadeesh (2003) [7]. Adequate level of available K in red soils of the study area may be due to the prevalence of K-rich clay minerals like illite and kaolinite. 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. The highest water soluble K was obtained in Guttal soil and lowest water soluble K in Medleri-5 soil. The water soluble potassium was high in surface sample. The reason for this was due to addition of water soluble potash fertilizers at surface zone. Some amount of potassium availed due to weathering and mineralisation. Similar results were obtained by Jagadeesh (2003) [7], Lakaria *et al.* (2012) [11] and Bangroo *et al*. (2014) [2]. The exchangeable potassium content of red soils ranged from 44.80 to 78.40 mg kg^{-1} with a mean of 52.28 mg kg^{-1}. The highest exchangeable potassium was obtained in soil of Aremallapur-5 for and lowest value was recorded for Aremallapur-4 soil. The exchangeable potassium was high because of high exchange sites offered for K fertilization and also addition of organic manures which might have enhanced the exchangeable K in solution phase. The results are on par with the findings of Divya *et al*. (2016) [4]. The non-exchangeable potassium of red soils ranged from 495.88 to 653.66 mg kg^{-1} with a mean of 581.53 mg kg^{-1}. The lowest non-exchangeable potassium was obtained in Medleri-

5 soil and highest was obtained in Aremallapur-4 soil. The non-exchangeable K was low due to release of potassium from reserve pool to compensate the loss of water soluble and exchangeable K by plant uptake. The similar findings were obtained by Kundu *et al*. (2014) [10] and Divya *et al*. (2016) [4]. The lattice potassium of red soils ranged from 0.92 to 1.28 per cent with an average value of 1.20 per cent. The lattice potassium of red soils ranged from 0.92 to 1.28 per cent with a mean of 0.98 per cent. The highest lattice potassium was obtained in Aremallapur-5 soil and lowest in Kenagapur-1 soil. The high values of red soil type 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 lattice K content varied among the samples. The results corroborated with the findings of Divya *et al*. (2016) [4]. The total potassium in surface depth of red soils varied from 0.97 to 1.35 per cent with a mean of 1.16 per cent. The total K was recorded highest in Aremallapur-5 soil and lowest in Savanur soil. The degree of weathering is important for the total content of potassium in soils. Depending on clay mineralogy, lattice K content and organic matter content, the total K content varied in surface layer. The results are in comparison with those of research findings of Hebsur and Gali (2011) [5], Jagmohan and Grewal (2014) [8] and Divya *et al*. (2016) [4].

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: Physico-chemical properties in selected maize growing red soils of Haveri district, Karnataka

Sample No.	$pH_{1:2.5}$	$EC_{1:2.5}$ (dS m^{-1})	OC (g kg^{-1})	Sand	Silt	Clay	EPP	CEC	Sum of Exch. Cations	PAR	Available K_2O (kg ha^{-1})	Textural class
				←	%		→	← [cmol (p^+) kg^{-1}]	→			
1	6.59	0.05	6.04	60.96	16.74	21.33	14.33	15.21	14.19	2.23	328.56	scl
2	6.75	0.06	4.50	55.11	18.10	25.04	12.92	19.34	18.01	1.91	376.32	scl
3	6.50	0.03	5.01	56.71	18.20	24.16	8.75	23.65	20.83	1.08	274.30	scl
4	6.70	0.04	5.72	55.23	17.52	25.54	10.95	19.36	17.93	1.94	321.12	scl
5	6.66	0.03	5.35	60.36	17.04	22.11	12.47	16.92	15.36	0.89	271.80	scl
6	7.50	0.25	5.20	55.42	18.54	24.44	9.88	21.86	19.84	1.51	312.96	scl
7	6.68	0.03	4.63	52.48	19.11	27.23	14.49	24.15	22.59	2.98	483.84	scl
8	6.50	0.05	5.12	56.56	18.10	24.55	12.14	16.88	15.24	0.89	302.16	scl
9	6.75	0.04	5.78	36.32	25.67	36.73	8.32	26.32	23.85	2.12	322.56	cl
10	7.36	0.19	6.11	60.84	16.88	21.45	15.41	16.22	14.64	2.67	430.08	scl
11	7.30	0.18	5.07	55.42	18.40	23.64	9.27	22.76	19.80	1.10	268.80	scl
12	7.40	0.18	5.19	39.78	25.88	33.03	9.24	27.05	24.13	1.65	430.08	cl
13	7.41	0.09	6.40	60.39	16.85	21.98	11.93	18.43	16.27	1.85	341.26	scl
14	6.68	0.11	5.10	57.18	18.60	24.11	10.74	20.29	18.70	1.37	302.54	scl
15	7.24	0.22	6.20	58.81	16.87	23.13	13.07	17.21	15.22	1.38	323.51	scl
16	6.55	0.06	4.62	50.41	19.21	28.61	8.17	24.83	22.50	1.92	371.32	scl
17	6.38	0.07	6.90	59.17	15.76	24.78	10.89	18.36	16.34	0.95	269.80	scl
18	7.08	0.06	7.90	58.72	16.14	24.88	17.35	17.86	16.51	2.07	374.82	scl
19	7.00	0.05	7.00	47.30	22.84	29.37	9.20	23.14	20.62	2.21	376.22	scl
20	7.46	0.11	6.50	43.37	21.84	31.87	8.15	24.66	22.38	1.36	308.56	cl
Range	6.38-7.50	0.03-0.25	4.50-7.90	36.32 - 60.96	15.76 - 25.88	21.33 - 36.73	8.15-17.35	15.21-27.05	14.19-24.13	0.89-2.98	268.80-483.84	Sandy clay loam to clay loam
Mean	6.92	0.09	5.72	54.02	18.91	25.24	11.38	20.72	18.55	1.70	339.53	
S.D.	0.380	0.069	0.901	7.13	2.91	4.15	2.63	3.63	3.23	0.58	59.08	

Table 3: Forms and distribution of potassium in selected 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)	Surface (0-20 cm)	Surface (0-20 cm)	Surface (0-20 cm)	Surface (0-20 cm)
1	3.24	45.81	540.96	0.92	0.98
2	3.37	56.24	586.04	0.94	1.00
3	2.02	45.86	608.58	1.04	1.10
4	3.16	44.87	540.96	0.97	1.03
5	1.71	48.70	586.04	1.04	1.10
6	2.89	45.84	586.04	0.93	0.97
7	4.69	68.40	540.96	1.25	1.30
8	1.90	54.20	495.88	0.95	1.00
9	3.19	44.82	518.42	1.15	1.20
10	4.58	56.20	631.12	1.18	1.25
11	2.00	44.80	653.66	1.25	1.33
12	2.60	78.40	653.66	1.28	1.35
13	2.96	52.11	631.12	1.06	1.13
14	2.17	51.27	540.96	1.02	1.08
15	2.32	54.81	518.42	1.09	1.15
16	3.66	51.80	631.12	1.21	1.28
17	1.66	48.80	495.88	1.15	1.20
18	3.36	56.00	608.58	1.24	1.30
19	4.02	49.01	631.12	1.21	1.28
20	2.61	47.82	631.12	1.18	1.25
Range	1.66-4.69	44.80-78.40	495.88-653.66	0.92-1.28	0.97-1.35
Mean	2.91	52.28	581.53	1.11	1.16
S.D.	0.89	8.41	53.03	1.18	1.26

4. Conclusion
The result of the present investigation suggests that maximum K content of maize growing Haveri soils is in the non-exchangeable form, mostly fixed up within the clay lattice rendering very small amount of available 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 and crop. A future study on clay mineralogical make-up of the soils may help calibrating the reserve pool of K and the extent of its mining. This may help the planners to formulate an effective K fertilizer program for the soils of the region.

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