The Pharma Innovation Journal 2022; 11(11): 2472-2479

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(11): 2472-2479

www.thepharmajournal.com
Received: 09-08-2022
Accepted: 16-09-2022

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Potassium fixation capacity and potassium release in profiles of different land use systems in southern transect of Bengaluru

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Abstract

Potassium fixation of soils is an important phenomenon affecting the status of soil K and its availability to crops. It is the process in which soils converting exchangeable or water soluble potassium to fixed form in the inter lattice position of clay minerals. Potassium releasing power refers to the inherent capacity of the soil to supply K to growing plant from its natural source. The present study was undertaken to know the potassium fixation and release characteristics in the profile soil samples of southern transect of Bengaluru. The results prevailed that the average highest rate of potassium fixation was observed in the profile-8(0.41 cmol (p+) kg^{-1}) and lowest in the profile-2 (0.17 cmol (p+) kg^{-1}). The total step potassium release from surface soils of mulberry, agriculture, vegetable and plantation land use profiles ranged from 143 to 578, 99 to 175, 83 to 106 and 63 to 139 mg K kg^{-1}, respectively. Constant rate K varied within the narrow limit of 3 to 20 mg kg^{-1} in spite of wide variations in step K contents of the soils.

Keywords: Potassium fixation, Potassium release, step K and constant K

Introduction

Potassium (K) is abundant in most soils across the world. However, its availability to crops is influenced by many factors, including the type of primary and secondary minerals present in the soil, climatic conditions, intensity of mineral weathering, the thickness of vegetation in the region, the soil's organic matter content and the application of potassic fertilizers. Soils differ greatly in terms of the type and amount of clay formed by weathering of primary minerals and mechanical composition. The reaction of these clay minerals with other solids in soil and soil solution may vary over time due to varying influences of climatic conditions and farm management practices. As a result, the behaviour of various forms of potassium in soil, particularly the fraction held by clay minerals, may vary significantly.

The term "fixation", as it applied to potassium in soils, refers to the conversion of water-soluble potassium to insoluble, non-replaceable forms. It is generally considered that the water-soluble and replaceable soil potassium constitute the forms of this element that are most readily utilized by plants. The problem of potassium fixation has considerable practical importance directly concerns the availability to plants of an essential nutrient often applied in fertilizers.

The most extensively used extractant for extracting available potassium in soil is neutral normal ammonium acetate. However, the majority of the researchers emphasized the inadequacy of any single method to cover the various types of soils and for soil having less than 20 per cent clay, the Barber and Margons approach is more appropriate for determining exchangeable K. Potassium release capability was also shown to be reliable for estimating potassium availability to crops.

Soil K releasing capacity varies significantly depending on clay mineralogy, soil texture, moisture regimes, and wetting and drying cycles. Soils with low K status may not respond to fertilizer K if the K releasing power is high. Thus, the characteristic of K fixation and release indicates potassium availability in rainfed and irrigated agroecosystems.

Material and Methods

Study region

In the context of a larger study that investigates social-ecological transition processes in the rural-urban interface of the South Indian Metropolis, Bengaluru, two transects (northern and southern transect) were defined as a common space for interdisciplinary research. The northern transect (N-transect) is a rectangular strip of 5 km width and 50 km length and the southern transect (S-transect) is a polygon covering a total area of 300 km^2. The corner co-ordinates of southern transect of Bengaluru are presented in Table 1. The red area corresponds to the districts under Bengaluru's administrative authorities. The outer ring road is shown in yellow. The blue contours indicate the northern and southern research transects and the star marks the reference point (Vidhana Soudha) in the city centre (Fig. 1 and 2) (Hoffmann *et al.*, 2017) [10].

Table 1: Corner coordinates of the southern transect of Bengaluru

S- Transect	
Latitude	**Longitude**
N 12° 54' 54"	E 77° 32' 25"
N 12° 53' 43"	E 77° 34' 54"
N 12° 44' 40"	E 77° 32' 19"
N 12° 40' 04"	E 77° 28' 39"
N 12° 40' 03"	E 77° 24' 21"
N 12° 45' 17"	E 77° 23' 41"

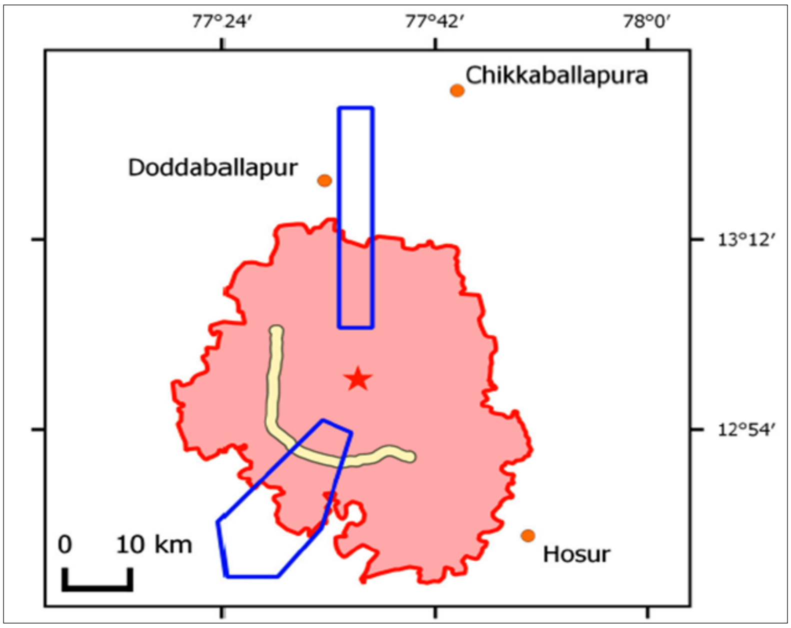

Fig 1: Rrural–urban interface of Bengaluru

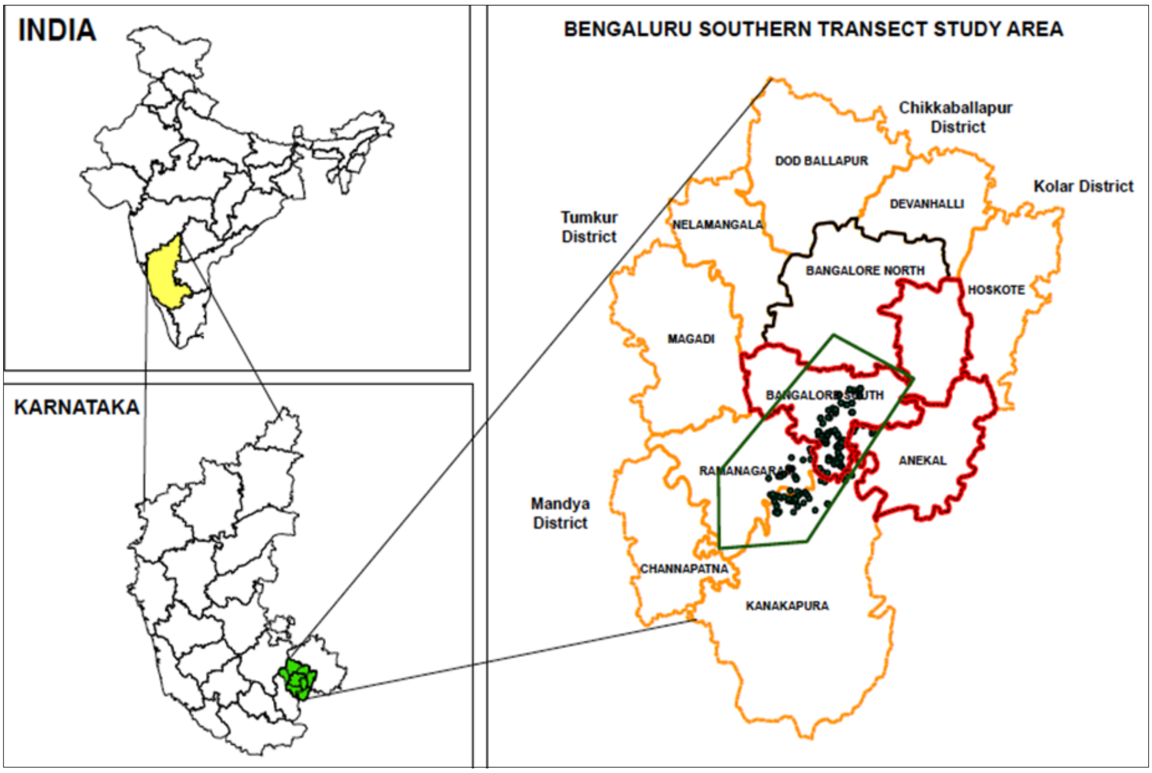

Fig 2: Location map showing study area (Southern transect of Bengaluru)

Preliminary survey was carried out to know the dominant land use systems around the southern transect. Finger millet, maize, millets, pulses were grouped under conventional agricultural crops. Vegetable crops identified were chilli, cabbage, cauliflower, tomato, brinjal, capsicum *etc*., and wider spaced long duration plantation crops like coconut, banana, mango, sapota, *etc.*, whereas mulberry is major commercial crop next to these groups in the southern transect. Eight profiles were studied in different landforms (Mulberry, agriculture, vegetable and plantation) in southern transect of Bengaluru. Site characteristics of these typifying profiles are given in Table 2 and the coordinates are furnished in Fig. 3.

The horizon-wise eight profile samples from different land use systems in southern transect of Bengaluru were collected. The collected soil samples were analysed for K fixation capacity and K release capacity i.e., step K and constant rate K. K fixation capacity was determined by the wetting and drying method as described by Volk (1934) [14]; step K and constant rate K were undertaken in the laboratory by using 1 $\underline{N}$ HNO$_3$ extractant to assess long term behaviour of potassium under intensive cropping and to judge the availability of nonexchangeable K to crops under intensive cropping. Potassium estimation in the extracts was carried out with the help of a flame photometer.

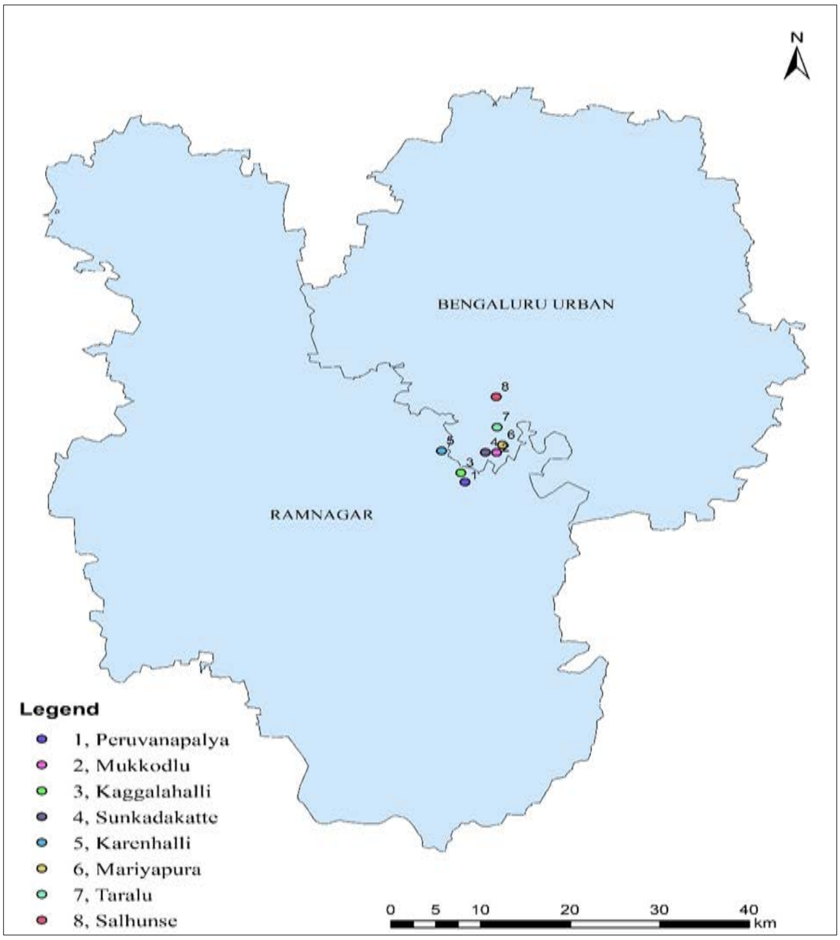

Fig 3: Location details of profiles in areas of southern transect of Bengaluru

Results and Discussion

Potassium fixation (cmol (p$^+$) kg^{-1})

The data related to potassium fixation capacity in different land use system profiles of southern transect of Bengaluru are presented in Table 3 and Fig. 4a & 4b.

The potassium fixation capacity of mulberry land use profiles ranged from 0.08 to 0.17 cmol (p$^+$) kg^{-1} in surface soils, whereas, in sub-surface soils potassium fixation capacity varied from 0.13 to 0.27 cmol (p$^+$) kg^{-1}. The potassium fixation capacity of agriculture land use profiles ranged from 0.09 to 0.11 cmol (p$^+$) kg^{-1} in surface soils, whereas, in sub-surface soils potassium fixation capacity varied from 0.12 to 0.39 cmol (p$^+$) kg^{-1}. The potassium fixation capacity of vegetable and plantation land use profiles ranged from 0.03 to 0.23 and 0.08 to 0.30 cmol (p$^+$) kg^{-1} in surface soils, respectively. The mean values of potassium fixation were 0.23, 0.17, 0.25, 0.18, 0.31, 0.24, 0.27 and 0.41 cmol (p$^+$) kg^{-1} in all the profiles (1 to 8), respectively. The highest average potassium fixation was in profile-8 (0.41 cmol (p$^+$) kg^{-1}) and lowest was found in profile-2 (0.17 cmol (p$^+$) kg^{-1}). The lowest K fixation might be related to the K saturation of the exchange complex of the soils and the nature and amount of clay minerals, as evident from very low K fixation by soil.

Availability of added potassium to plants is controlled by various factors and among them fixation of potassium in soil is most important. The result of the potassium fixation study revealed that the soils showed marked difference in potassium fixation capacity which was attributed to difference in their physical and chemical properties; particularly clay content, nature of clay, CEC, pH and exchangeable cations. Sub-surface soils have higher K fixation than surface soil its due to increasing the clay content with depth and lower organic carbon content (Bisnoi and Khatri, 1974) [3]. Higher K fixation was in sub-surface soil than surface soil due to fact that amount of clay content increased with depth. Similar results were reported by Boruah *et al.* (1990) [1]. An increase in finer fractions of soils means the greater surface area and thus more the number of fixation sites and consequently increased potassium fixation.

In general, it was noticed that higher K fixing capacity in Bt subsurface horizon than BC layer in some profiles. The inconsistent depth wise decrease or increase in K fixation capacity could be due to variability in intensity of pedoturbation process, nature and quantity of K fixing minerals. Similar results were observed by Srinivasa Rao Ch. *et al*. (2000) [13] in the soils of India.

Since these soils are dominated by kaolinite type of clay and fixation was found to be low. According Barber (1979) [2] K fixing capacity accounts for 19 to 32 per cent by sieve mechanism. Furthermore, fixation and release of K was found be reversible process and it was controlled by type and particle size of the primary and secondary minerals and this process is affected by liming, manuring, temperature, freezing and thawing and the action of plant roots (Goulding, 1987) [8].

Potassium release characteristics

The horizon wise cumulative K release, step K and constant rate K in different profiles are presented in the Table 4 and Fig. 5a & 5b.

Cumulative potassium release

The cumulative potassium release from surface soils of mulberry land use profiles (1 & 2) ranged from 200 to 718 mg K kg^{-1}. The lowest and the highest cumulative K release values were registered by BC horizon (73 mg K kg^{-1}) and Ap horizon (718 mg K kg^{-1}) in mulberry land use system profiles. The cumulative potassium release from surface soils of agriculture, vegetable and plantation land use profiles ranged from 140 to 280 mg K kg^{-1}, 139 to 211 mg K kg^{-1} and 87 to 181 mg K kg^{-1}, respectively. The cumulative K released was irregular down the profile.

The cumulative K release computed by the summation of K released up to seventh extractions is presented in Table 4.13. The pattern of distribution of cumulative K release followed almost the same trend as in non-exchangeable K, step K and constant rate K. Major portion of cumulative K from all most all the profiles was released by the fourth extraction with the reagent *viz*., 1N HNO_3. The soil horizons containing relatively higher amounts of non-exchangeable K recorded higher amounts of cumulative K than those with lower amounts of non-exchangeable K. Similar results were reported by Divya *et al*. (2016) [6].

The results of the present study suggests that the soils, irrespective of the amount of total or the different forms of K, released a substantial proportion of cumulative K which probably included the major portion of the so-called non-exchangeable K relatively easily upon depletion of the exchangeable K from the exchange complex. On the other hand, relatively lower amounts of cumulative K were noticed in profile-7 and 8. This could be attributed to the presence of relatively lower amounts of illites and the micaceous minerals in soils. Similar observation was made by Agarwal (1965) [1]; Boruah *et al.* (1990) [1]. The lower cumulative K release from coarse textured soils than fine textured soils was also reported by Jagadeesh, 2003 [11].

Total step potassium

It indicates potential of K release for certain period and suggests the availability of potassium for sub-sequent cropping season. By repeated extractions with boiling 1N HNO_3, two categories of non-exchangeable K were distinguished, namely 'Step K' which was determined by subtracting the 'constant rate K' from the successive extractions and summing up of all the successive components, the step K values of the soils, designated as the plant utilizable non-exchangeable K (Haylock, 1956) [9]. The second one is 'Constant rate K' (CR-K) which occurred in similar amounts in each extraction for each soil.

The total step potassium release from surface soils of mulberry, agriculture, vegetable and plantation land use profiles ranged from 143 to 578, 99 to 175, 83 to 106 and 63 to 139 mg K kg^{-1}, respectively. The lowest and the highest total step K-release values were registered by BC horizon of profile-7 (25 mg K kg^{-1}) and Ap horizon of profile-2 (578 mg K kg^{-1}), respectively. The pattern of distribution of step K release followed almost the same trend as in non-exchangeable K, cumulative K and constant rate K.

However, the amount of step K does not exceed the amount of non-exchangeable K for each soil measured by the conventional single extraction with boiling 1N HNO_3. Thus, the more the amount of step K in soil, the more is expected to be the plant utilizable non-exchangeable K. The ratio of step K to non-exchangeable K may be used as a better index of mobilization of non-exchangeable K reserves in different soils (Dhar and Sanyal, 2000) [5]. This proposition in the present study seems to reflect the quantum of total non-exchangeable K availability in soil and total K release for crop nutrition and hence needs exhaustive field investigations for confirmation. Haylock (1956) [9] suggested that the soils would become responsive to potassium fertilizer when step K is about 3.0 me kg^{-1} soil or less and non-responsive when the value is about 5.0 me kg^{-1} soil or more.

Constant rate potassium

The constant rate potassium (CR-K) content of surface soils of mulberry, agriculture, vegetable and plantation land use profiles varied from 8 to 20, 6 to 15, 8 to 15 and 4 to 6 mg kg^{-1}, respectively and recorded irregular trend down the profile.

The constant rate K of the soils as a measure of availability index of K under long-term basis varied within the narrow limit of 3 to 20 mg kg^{-1} in spite of wide variations in step K contents of the soils (Table 4). These values accomplished a constant level at the fifth to seventh extractions with boiling 1N HNO_3, thereby indicating that there were still considerable amounts of K reserve even after the 7th extractions and that had a definite solubility in hot 1N HNO_3.

The release of K at constant rate started at fifth extraction in all soils. This suggests that the curtailment of K releasing power is likely to be similar in all the profiles. The constant rate K indicates the presence of 'structural K' or 'interlayer K'. It is very slowly but constantly transformed into available form for the crops over a longer period under exhaustive cropping provided with no external supply of K fertilizers. Other research workers Ghosh and Ghosh, 1976 [7]; Sailakshmeshwari *et al.* (1985) [12] have also reported about obtaining CR-K after 6th to 7th extractions with HNO_3 in soils of Nagaland and Andhra Pradesh.

Table 2: Site characteristics of profiles in southern transect of Bengaluru

Profile	Sites	Latitude	Longitude	Slope (%)	Erosion	Drainage	Runoff	Parent material	Land use
1	Peruvanapalya	12° 43′ 18.2″	77° 29′ 27.5″	3-5 %	Moderate	Well	Medium	Granite	Mulberry
2	Mukkodlu	12° 45′ 36.37″	77° 31′ 21.93″	1-3 %	Slight	Well	Medium	Granite	Mulberry
3	Kaggalahalli	12° 44′ 01.5″	77° 29′ 13.1″	0-1 %	Slight	Well	Slow	Granite	Agricultural
4	Sunkadakatte	12° 45′ 36.81″	77° 30′ 41.31″	1-3 %	Slight	Well	Medium	Granite	Agricultural
5	Karenhalli	12° 45′ 44.2″	77° 28′ 2.6″	3-5 %	Moderate	Well	Medium	Granite, Gneiss	Vegetable
6	Mariyapura	12° 46′ 11.60″	77° 31′ 42.46″	5-10 %	Moderate	Well	Rapid	Granite, Gneiss	Vegetable
7	Taralu	12° 47′ 34.28″	77° 31′ 23.31″	1-3 %	Slight	Moderately Well	Slow	Granite	Plantation
8	Salhunse	12° 49′ 55.43″	77° 31′ 20.30″	0-1 %	Slight	Well	Slow	Granite	Plantation

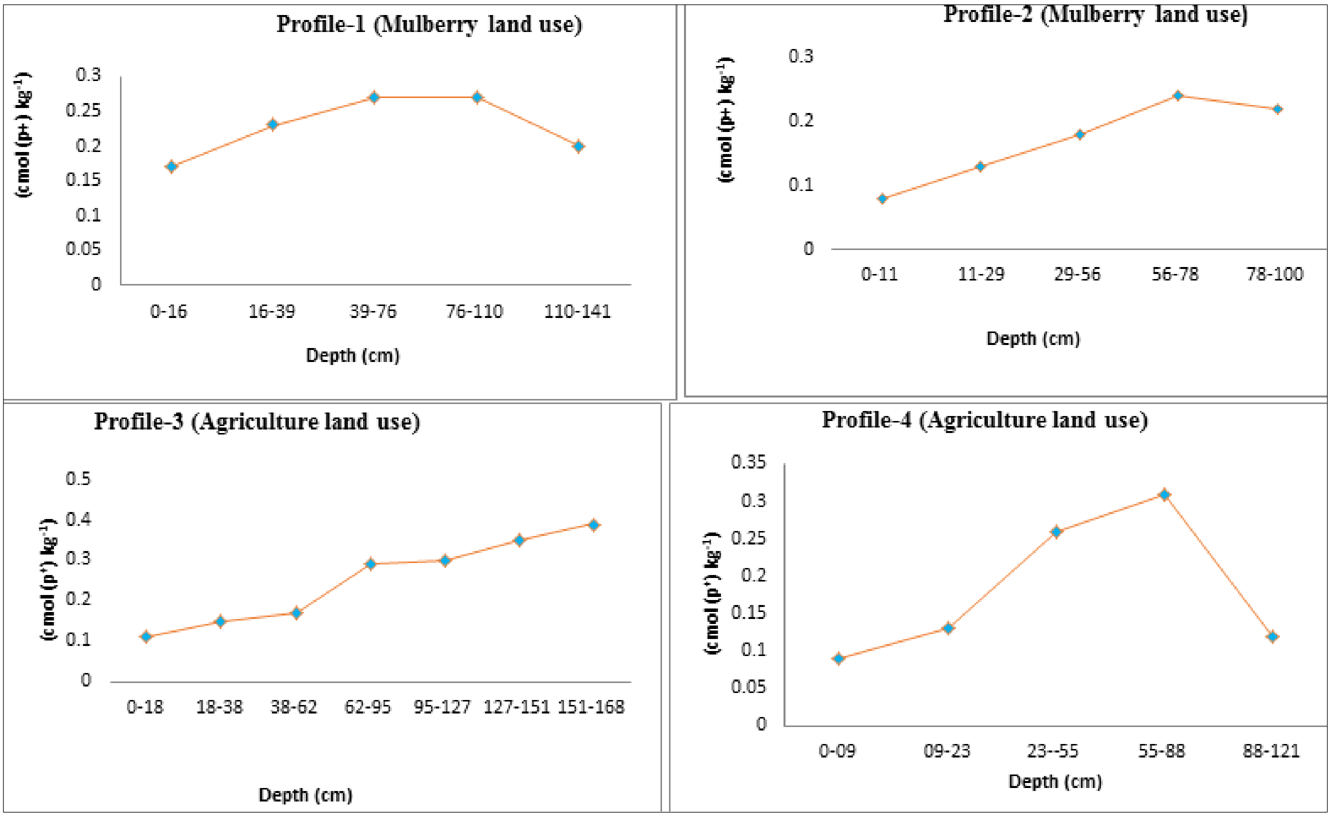

Fig 4a: Potassium fixation capacity in profile soils of southern transect of Bengaluru

Table 3: Potassium fixation capacity in profile soils of southern transect of Bengaluru

Horizons	Depth (cm)	Potassium fixation capacity (cmol (p$^+$) kg^{-1})	Horizons	Depth (cm)	Potassium fixation capacity (cmol (p$^+$) kg^{-1})
Profile-1 (mulberry land use)			**Profile-5 (vegetable land use)**		
Ap	0-16	0.17	Ap	0-10	0.03
Bt$_1$	16-39	0.23	Bt$_1$	10-35	0.14
Bt$_2$	39-76	0.27	Bt$_2$	35-67	0.39
Bt$_3$	76-110	0.27	Bt$_3$	67-107	0.46
BC	110-141	0.20	2Bt$_4$	107-130	0.54
WPM	141+		WPM	130+	
Mean		0.23	Mean		0.31
Profile-2 (mulberry land use)			**Profile-6 (vegetable land use)**		
Ap	0-11	0.08	Ap	0-15	0.23
Bt$_1$	11-29	0.13	Bt$_1$	15-30	0.27
Bt$_2$	29-56	0.18	2Bt$_2$	30-48	0.35
Bt$_3$	56-78	0.24	BC	48-68	0.10
BC	78-100	0.22	WPM	68+	
WPM	100+		Mean		0.24
Mean		0.17	**Profile-7 (plantation land use)**		
Profile-3 (agriculture land use)			Ap	0-15	0.08
Ap	0-18	0.11	Bt$_1$	15-41	0.24
Bw$_1$	18-38	0.15	Bt$_2$	41-76	0.26
Bw$_2$	38-62	0.17	Bt$_3$	76-103	0.26
Bw$_3$	62-95	0.29	Bt$_4$	103-145	0.37
Bw$_4$	95-127	0.30	BC	145-160	0.42

Bw$_5$	127-151	0.35	WPM	160+	
BC	151-168	0.39	Mean		0.27
WPM	168+		**Profile-8 (plantation land use)**		
Mean		0.25	Ap	0-11	0.30
Profile-4 (agriculture land use)			Bt$_1$	11-34	0.43
Ap	0-09	0.09	Bt$_2$	34-60	0.45
Bt$_1$	09-23	0.13	Bt$_3$	60-83	0.47
Bt$_2$	23—55	0.26	WPM	83+	
Bt$_3$	55-88	0.31	Mean		0.41
Bt$_4$	88-121	0.12			
WPM	121+				
Mean		0.18			

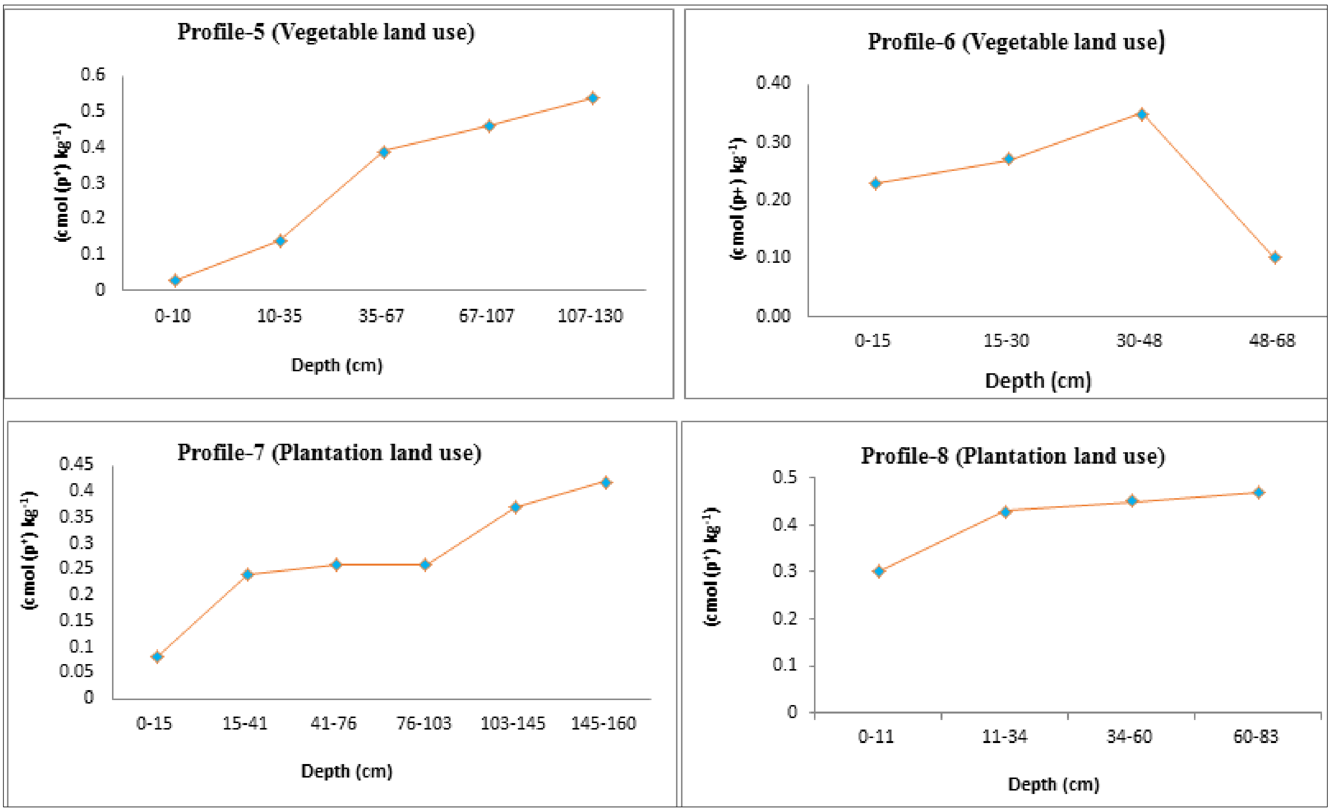

Fig 4b: Potassium fixation capacity in profile soils of southern transect of Bengaluru

Table 4: The release of potassium with boiling IN HNO$_3$, step potassium and constant rate potassium in different soil horizons of southern transect of Bengaluru

Horizons	**Depth (cm)**	**K extracted by boiling 1N HNO$_3$ (mg kg^{-1})** Successive extraction number							**Cumulative K release (mg K kg^{-1})**	**Total step-K (mg K kg^{-1})**	**CR-K (mg K kg^{-1})**
		I	**II**	**III**	**IV**	**V**	**VI**	**VII**			
Profile-1 (mulberry land use)											
Ap	0-16	68	54	34	20	8	8	8	200	143	8
Bt$_1$	16-39	36	28	21	18	7	7	7	125	74	7
Bt$_2$	39-76	32	25	23	19	7	6	7	119	67	7
Bt$_3$	76-110	41	33	19	16	7	7	7	128	83	7
BC	110-141	23	18	16	15	6	5	6	89	47	6
WPM	141+										
Profile-2 (mulberry land use)											
Ap	0-11	256	205	147	50	20	19	20	718	578	20
Bt$_1$	11-29	165	132	57	34	14	12	12	424	340	12
Bt$_2$	29-56	41	33	30	25	10	9	10	158	88	10
Bt$_3$	56-78	23	18	19	22	9	9	9	109	49	9
BC	78-100	16	12	15	14	6	5	5	73	35	5
WPM	100+										
Profile-3 (agriculture land use)											
Ap	0-18	48	38	22	15	6	6	6	140	99	6
Bw$_1$	18-38	34	27	23	15	6	6	6	117	75	6
Bw$_2$	38-62	31	25	29	24	10	10	10	139	70	10

Bw_3	62-95	30	24	23	19	8	8	8	120	66	8
Bw_4	95-127	26	21	21	19	8	8	8	110	56	8
Bw_5	127-151	27	22	22	18	7	7	7	109	60	7
BC	151-168	33	26	30	27	11	11	11	148	71	11
WPM	168+										
Profile-4 (agriculture land use)											
Ap	0-09	82	65	44	42	17	15	15	280	175	15
Bt_1	09-23	101	81	38	27	11	10	10	278	208	10
Bt_2	23—55	109	87	38	19	7	7	7	274	225	7
Bt_3	55-88	56	45	35	33	13	13	13	209	118	13
Bt_4	88-121	56	44	34	29	12	11	11	197	120	11
WPM	121+										
Profile-5 (vegetable land use)											
Ap	0-10	35	28	30	21	8	8	8	139	83	8
Bt_1	10-35	33	27	30	27	11	10	11	148	73	11
Bt_2	35-67	44	36	36	23	9	10	9	167	104	9
Bt_3	67-107	64	51	44	21	9	8	8	206	150	8
$2Bt_4$	107-130	43	35	33	24	9	9	9	162	99	9
WPM	130+										
Profile-6 (vegetable land use)											
Ap	0-15	46	37	42	40	16	15	15	211	106	15
Bt_1	15-30	34	27	21	20	8	7	7	123	74	7
$2Bt_2$	30-48	38	30	30	25	10	10	10	153	83	10
BC	48-68	40	32	25	21	8	8	8	142	86	8
WPM	68+										
Profile-7 (plantation land use)											
Ap	0-15	30	24	12	10	4	4	4	87	63	4
Bt_1	15-41	15	12	8	8	3	3	3	52	31	3
Bt_2	41-76	12	10	11	8	3	3	3	50	29	3
Bt_3	76-103	16	12	9	9	4	4	4	57	32	4
Bt_4	103-145	15	12	11	10	4	4	4	60	32	4
BC	145-160	12	9	8	7	3	3	3	45	25	3
WPM	160+										
Profile-8 (plantation land use)											
Ap	0-11	61	49	40	14	6	6	6	181	139	6
Bt_1	11-34	20	16	19	15	6	6	6	88	46	6
Bt_2	34-60	23	18	19	19	7	7	7	100	51	7
Bt_3	60-83	17	13	12	9	4	4	4	62	34	4
WPM	83+										

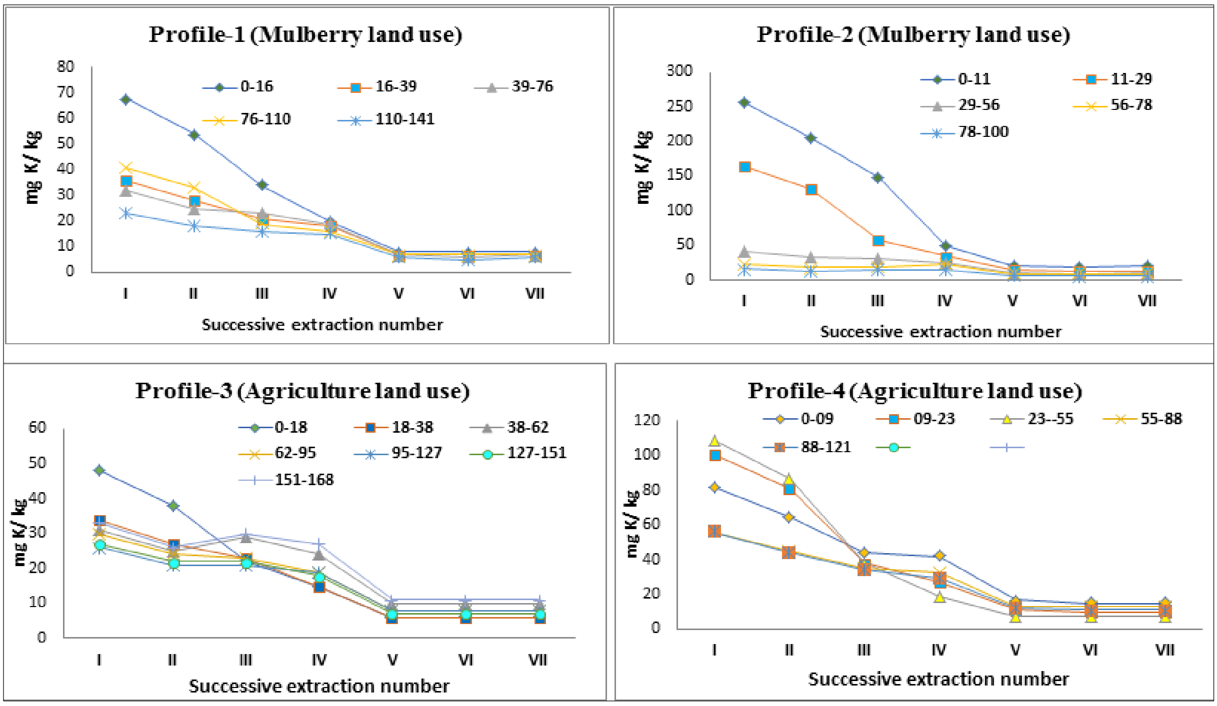

Fig 5a: The potassium release with boiling IN HNO_3, step potassium and constant rate potassium in different soil horizons of southern transect of Bengaluru

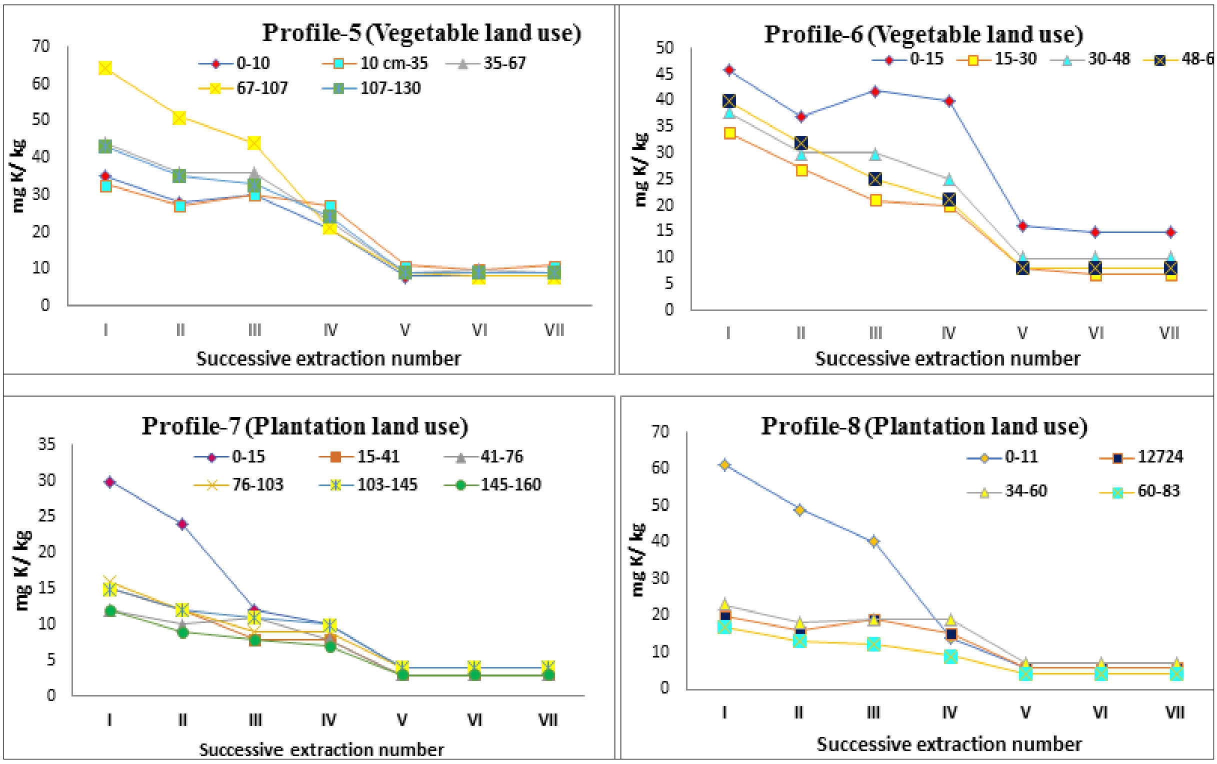

Fig 5b: The potassium release with boiling IN HNO_3, step potassium and constant rate potassium in different soil horizons of southern transect of Bengaluru

Conclusion

The mean values of potassium fixation were 0.23, 0.17, 0.25, 0.18, 0.31, 0.24, 0.27and 0.41 cmol (p^+) kg^{-1} in all the profiles (1 to 8), respectively. The highest average potassium fixation was in profile-8 (0.41 cmol (p^+) kg^{-1}) which was under plantation land use and lowest was found in profile-2 (0.17 cmol (p^+) kg^{-1}) which was under agriculture land use system. The cumulative K released was irregular down the profile. The pattern of distribution of cumulative K release followed almost the same trend as in non-exchangeable K, step K and constant rate K. Major portion of cumulative K from all most all the profiles was released by the fourth extraction with the reagent *viz*., 1N HNO_3.

Acknowledgement: We are thankful to KSTePS, Department of Science and Technology, Govt. of Karnataka for financial support.

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