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Potassium fixation and release pattern in selected black soil series of Kavalur sub-watershed of Koppal district, Karnataka

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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 surface and sub-surface samples of Kavalur sub-watershed of Koppal district. The K release characteristics of soils were determined by employing successive extraction of soil with boiling 1*N* HNO_3 and the potassium fixation was studied by taking representative samples from surface and subsurface soil. The results prevailed that the highest rate of potassium fixation was observed in the AWD (1.41 cmol (p^+) kg^{-1}) soil series and lowest in the GRH (0.61 cmol (p^+) kg^{-1}) soil series in surface soils whereas, in sub-surface soils highest rate of fixation capacity was observed in the AWD (1.44 cmol (p^+) kg^{-1}) soil series and lowest in GRH (0. 64 cmol (p^+) kg^{-1}) soil series. Sub-surface soil recorded highest fixation capacity compare to surface soil. The cumulative K release from different soil series ranged from 329 to 975 mg K kg^{-1} in surface soils whereas, in sub-surface soils were ranged from 328 to 1012 mg K kg^{-1}. The constant rate potassium (CR-K) content of soils as influenced by long term soil fertility management were ranged from 4 to 24 mg K kg^{-1} in the surface soils and 4 to 20 in sub-surface soils. Total step- K of surface soils ranged from 269 to 687 mg K kg^{-1} whereas, in sub-surface soils ranged from 274 to 792 mg K kg^{-1}.

Keywords: Potassium, fixation, k release, cumulative k, total step k, constant rate k.

Introduction

The nature of the different forms of potassium equilibrium is variable and depends upon the soil type and nature of the clay minerals. The readily available K constitutes only 1 to 2 per cent of total K and exists in soil in two forms, viz., solution K and exchangeable K adsorbed on soil colloidal surface (Brady and Weil, 2002) [5]. These forms remain in dynamic equilibrium with one another. The readily available K or water soluble K has been reported to be a dominant fraction in the initial stage while, exchangeable K and non-exchangeable K contribute more in the later stages of crop growth. According to increasing order of plant availability, soil K exists in four forms i.e. mineral K (5000-25000 mg kg-1), non-exchangeable K (50-750 mg kg-1), exchangeable K (40-600 mg kg-1) and solution K (1-10 mg Kg-1). K cycling or transformations among the K forms in soils are dynamic. Soils that are rich in vermiculite and micas can have large amounts of non-exchangeable K, whereas, soils containing kaolinite, quartz and other siliceous minerals contain less available and exchangeable K (Martin and Sparks, 1985) [12].

The term "fixation", as it applied to potassium in soils, refers to the reversion of water-soluble potassium to difficultly soluble, 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 K releasing capacity of the soils differ markedly with clay mineralogical make up, soil texture, moisture regimes and wetting and drying cycles. Low K status soils may not show response to fertilizer K, if the K releasing power is high. Thus, K fixation and release characteristic indicates potassium availability under rainfed and irrigated agro ecosystems. The Kavalur sub-watershed located in Koppal taluk of Koppal district has diversified crop, climate and soils. Hence, the study on heterogeneity of soils of Kavalur with respect to fixation capacity and release pattern of K were studied to understand the current need of fertilizer management in general and potassium management.

Material and Methods
The surface samples were collected based on soil heterogeneity and slope in sub-watershed of Koppal district and studied during 2017-18 at UAS, Dharwad. The annual rainfall of the region is 572.37 mm (Anon., 2016) [3]. The Kavalur sub-watershed is located between 15^0 15′ 35.2″ and 15^0 18′ 30.1″ N latitude and 75^0 54′ 56.7″ and 75^0 57′ 28.9″ E longitude. The collected soil samples 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.

Potassium fixation capacity of soils
The procedure suggested by Jackson (1973) [10] was followed to determine potassium-fixing capacity of soils. 10 ml KCl solution containing 10 mg of K was added to 10 g of soil taken in a 250 ml conical flask. The soil-water suspension was evaporated to dryness on a steam bath. The dried soil sample was then treated with 5 ml of KCl solution plus 5 ml of distilled water and was evaporated to dryness. After that, the soil was treated with 2.5 ml of KCl solution plus 7.5 ml of water and the suspension was evaporated to dryness once again. Further, the soil was treated with 10 ml of only distilled water and was dried on the steam plate. The last step of treating the soil with water and evaporating the suspension to dryness on the steam bath was repeated 3 times. Finally, K in the dried sample was extracted with neutral *N* NH_4OAc and was measured using flame photometer.

One more sample (10 g) of the same soil was also taken separately in another conical flask and was treated with 10 ml of KCl solution containing 10 mg of K and the soil was immediately extracted with neutral *N* NH_4OAc and the K content was determined by flame photometer. The difference expressed as cmol (p+) kg^{-1} of soil was considered as the potassium fixing capacity of soil.

Potassium release characteristics of soils
The K release characteristics of soils were determined by employing successive extraction of soil with boiling 1*N* HNO_3 after removing exchangeable K as per the method described by Haylock (1956) [8].

Cumulative K release
One gram of soil was taken in a centrifuge tube and was treated with 10 ml of 1N HNO_3. The contents were heated for 10 min on a hot water bath and centrifuged for 10 minutes at 2000 rpm. The K in the supernatant liquid was determined with the help of flame photometer. To the same soil, another 10 ml of 1*N* HNO_3 was added and the same procedure of boiling the sample, centrifugation and K estimation was followed. The above process was repeated till the amount of K released in successive extractions was constant. The cumulative K released was calculated by adding all the values of K extracted by successive extractions. Further,

Haylock's step-K and constant rate-K (CR-K)
Haylock's step-K: The amount of total step K was calculated as Haylock's step K = {(The amount of K extracted (cumulative) by boiling 1*N* HNO_3 till constancy in K release is reached) – (The amount of CR-K x Total number of extractions)}.

Constant Rate Potassium (CR-K)
After several repeated extractions of soil by boiling 1*N* HNO_3, the potassium extracted reached a constant value. This constant value of K is designated as CR-K

Table 1: Details of soil samples collected from black soil types of Kavalur sub-watershed of Koppal district

S. No.	Series name	Series full name	Soil profile	Depth (cm)	Latitude (N)			Longitude (E)		
1	MTL	Muttal	Kav-4/R_9	0-16 and 16-49	15º	15′	39.8″	75°	57′	21.3″
2	DRL	Dambarahalli	Kav-4/T_1/P_1	0-24 and 24-51	15°	15′	57.8″	75°	57′	10.7″
3	BGP	Budagumpa	Kav-4/T_1/P_3	0-35 and 35-90	15°	15′	59.5″	75°	57′	28.9″
4	TSD	Thimmasandra	Kav-1/T_2/P_3	0-22 and 22-54	15°	16′	58.6″	75°	56′	19.0″
5	KAV	Kavalur	Kav-2/R_9	0-26 and 26-64	15°	18′	30.1″	75°	55′	44.9″
6	MLR	Murlapur	Kav-1/R_1	0-19 and 19-39	15°	15′	59.5″	75°	57′	28.9″
7	GRH	Gatareddihal	Kav-3/R_{11}	0-20 and 20-46	15°	17′	14″	75°	55′	47.8″
8	RNK	Revanki	Kav-3/R_2	0-11 and 11-32	15°	16′	18.1″	75°	56′	44.5″
9	AWD	Alawandi	Kav-2/T_1/P_2	0-30 and 30-66	15°	18′	20.3″	75°	55′	07.7″
10	BDR	Bardur	Kav-1/R_9	0-20 and 20-82	15°	17′	27.0″	75°	55′	17.8″
11	DRL-1	Degraded land	Kav-1/R_5	0-18 and 18-32	15°	17′	6.5″	75°	56′	44.5″
12	DRL-4	Degraded land	Kav-1/R_1	0-20 and 20-46	15°	16′	43″	75°	55′	56.6″

Table 2: Potassium fixation capacity in black soil series of Kavalur sub-watershed of Koppal district

S. No.	Black soil series	Potassium fixation capacity (cmol (p^+) kg^{-1})	
		Surface soils	Sub-surface soils
1	AWD	1.41	1.44
2	BDR	0.92	0.95
3	BGP	0.64	0.68
4	DRL	0.86	0.87
5	DRL-1	0.63	0.67
6	DRL-4	0.66	0.68
7	GRH	0.61	0.64
8	KAV	0.80	0.83
9	MLR	1.22	1.25
10	MTL	0.73	0.76
11	RNK	0.67	0.69
12	TSD	0.72	0.76
	Range	0.61-1.41	0.64-1.44
	Mean	0.82	0.85
	S.D.	0.25	0.25

Table 3: Potassium release characteristics in surface soils of black soil series of Kavalur sub-watershed of Koppal district

S. No	Black soil series	1	2	3	4	5	6	7	8	9	10	11	12	13	Cumulative K release (mg K kg-1)	Total step-K (mg K kg^{-1})	(CR-K mg K kg -1)
1	AWD	218	193	148	105	87	57	33	31	31	24	24	24	-	975	687	24
2	BDR	108	89	44	28	20	14	8	6	6	6				329	269	6
3	BGP	148	125	79	60	42	38	32	18	8	5	5	5	-	565	505	5
4	DRL	127	102	56	41	35	21	15	12	10	7	7	7	-	440	356	7
5	DRL-1	154	128	86	68	50	26	18	14	10	6	6	6	-	572	500	6
6	DRL-4	162	130	93	69	44	25	18	8	6	6	6	-	-	567	501	6
7	GRH	173	146	103	87	54	28	22	11	7	7	7	-	-	645	568	7
8	KAV	144	117	75	57	29	18	14	11	4	4	4	-	-	477	433	4
9	MLR	186	161	116	78	55	24	18	13	6	6	4	4	4	675	623	4
10	MTL	129	107	59	41	23	16	12	10	8	8	8	-	-	421	333	8
11	RNK	195	168	123	83	65	35	11	9	9	4	4	4	-	710	662	4
12	TSD	177	150	107	64	46	38	29	16	11	9	9	9	-	665	557	9
	Range														329-975	269-687	4-24
	Mean														586.75	499.50	7.50
	S.D.														168.36	131.67	5.43

Table 4: Potassium release characteristics in sub-surface soils of black soil series of Kavalur sub-watershed of Koppal district

S. No.	Black Soil series	1	2	3	4	5	6	7	8	9	10	11	12	13	Cumulative K release (mg K kg-1)	Total step-K (mg K kg^{-1})	CR-K (mg K kg -1)
1	AWD	228	213	167	128	89	55	39	33	20	20	20	-	-	1012	792	20
2	BDR	120	97	54	37	25	16	12	8	4	4	4	-	-	381	337	4
3	BGP	173	146	101	83	53	29	22	14	9	9	6	6	6	657	579	6
4	DRL	132	109	75	65	51	33	29	22	12	7	4	4	4	547	495	4
5	DRL-1	163	136	97	73	48	28	22	10	4	4	4	-	-	589	541	4
6	DRL-4	178	151	108	67	53	35	22	12	8	8	8	-	-	650	562	8
7	GRH	186	163	116	76	55	25	20	13	8	4	4	4	4	678	626	4
8	MLR	199	170	129	88	64	32	14	10	8	8	8	-	-	730	642	8
9	MNL	122	76	57	26	18	11	6	6	6	-	-	-	-	328	274	6
10	MTL	136	115	70	57	39	28	20	13	6	6	6	-	-	496	430	6
11	RNK	209	184	138	98	78	47	24	18	11	8	8	8	-	831	735	8
12	TSD	183	158	117	70	52	22	18	12	8	8	8	-	-	656	568	8
	Range														328-1012	274-792	4-20
	Mean														629.25	548.41	7.16
	S.D.														186.06	149.95	4.38

Results and Discussion

The potassium fixation capacity of black soil series ranged from 0.61 cmol (p^+) kg^{-1} to 1.41 cmol (p^+) kg^{-1} in surface soils. The sub-surface potassium fixation capacity of black soil series varied from 0.64 cmol (p^+) kg^{-1} to 1.44 cmol (p^+) kg^{-1}. The highest potassium fixation was in AWD (1.41 cmol (p+) kg^{-1} and 1.44 cmol (p^+) kg^{-1}) soil series for both surface and sub-surface soils. At both the depths the lowest value was recorded in GRH (0.61 cmol (p^+) kg^{-1} and 0.64 cmol (p^+) kg^{-1}) soil series. The mean values of potassium fixation were 0.82 cmol (p^+) kg^{-1} and 0.85 cmol (p^+) kg^{-1} in surface and sub-surface soils, respectively. 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. 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) [4]. 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. This may 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 from GRH series and high fixation by soil from AWD series the surface soil having very high amount of exchangeable K and more of kaolinitic clays. Sub-surface soil having low amount of exchangeable K and relatively larger amounts of illtic clay minerals along with kaolinites and also the total clay content was relatively higher in the AWD soil series as observation made by Anjali, 2017 [1]. Dinesh (1995) [6] have also reported similar results. K fixation was reported to be relatively higher in soils dominant in 2: 1 type of clay minerals than in soil dominant in 1:1 clay minerals (Ramanathan and Krishnamurthy, 1978) [14].

The cumulative potassium release from surface soils of black soil series ranged from 329 to 975 mg K kg^{-1}. The lowest and the highest cumulative K-release values were registered by soils of BDR (329 mg kg^{-1}) soil series and AWD (975 mg K kg^{-1}) soil series respectively. Average cumulative potassium release values in surface soils was 586.75 mg K kg^{-1}. The cumulative potassium release from sub-surface soils of black soil series ranged from 328 to 1012 mg K kg^{-1}. The lowest and highest cumulative K-release values were registered by soils of MNL (328 mg kg^{-1}) soil series and AWD (1012 mg K kg^{-1}) soil series respectively. Average cumulative potassium release values in surface soils was 629.25 mg K kg^{-1}. Mean cumulative K release in black soil series were 586.75 mg K kg^{-1} in surface and 629.25 mg K kg^{-1} in sub-surface soils, respectively. Black soil series had higher K release due to higher clay content and more 2:1 clay minerals like illities and vermiculite in AWD soil series than BDR and MNL soil series as observed by Anjali, 2017 [1]. Compared surface, sub-surface soil had higher K release due to clay content was increased with depth similar results are also found in Hebsur, (1997) [9] and Divya *et al.* (2016b) [7].

The total step potassium release from surface soils of black soil series ranged from 269 to 687 mg K kg^{-1}. The lowest and the highest total step K-release values were registered by soils of BDR (269 mg K kg^{-1}) soil series and AWD (687 mg K kg^{-1}) soil series respectively. Average total step potassium release values in surface soils were 499.50 mg K

kg^{-1}. The total step potassium release from sub-surface soils of black soil series ranged from 274 to 792 mg K kg^{-1}. The lowest and highest total step K-release values were registered by soils of MNL (274 mg K kg^{-1}) soil series and AWD (792 mg K kg^{-1}) soil series respectively. Average total step potassium release values in surface soils were 548.41 mg K kg^{-1}. In black soil series namely AWD, MLR shows higher total step K release than BDR, MTL soil series. Number of steps K observed in black soils were more than red soils. The range of values for interpretation of step K of soils suggested by Haylock (1956) [8] is considered, the soils can be classified under category III (>19.00 mg K per 100 g soil) *i.e.* soils which may not respond at present to the application of potash fertilizers (Jagadeesh, 2003) [11].

The constant rate potassium (CR-K) content of surface soils of black soil series ranged from 4 to 24 mg K kg^{-1}. The lowest CR-K was recorded by soils of KAV, MLR, RNK (4 mg K kg^{-1}) soil series and highest CR-K value was recorded by AWD (24 mg K kg^{-1}) soil series. Average CR-K value was 7.50 mg K kg^{-1}. The constant rate potassium (CR-K) content of sub-surface soils of black soil series ranged from 4 to 20 mg K kg^{-1}. The lowest CR-K was recorded by soils of BDR, DRL, DRL-1, GRH (4 mg K kg^{-1})soil series and the highest CR-K value was recorded by AWD (20 mg K kg^{-1}) soil series. Average CR-K value was 7.16 mg

kg^{-1}. Most of the soil series recorded the CR-K value at the 9th extraction itself, whereas few soil series recorded the CR-K at the 12th and 13th extraction. In case of black soil series constant rate potassium release highest in AWD soil series in surface and sub-surface. AWD soil series is dominated with 2:1 type clays so higher CR-K was recorded in AWD soil series. CR-K values increased with depth due to higher clay content (Divya *et al.*, 2016b) [7]. Metson (1968) [13] was in the opinion that CR-K of soils could be obtained after two or three extractions with extractant. However, in the present case, the CR-K for most of the soils was obtained by the 10th /11th extraction. Other research workers Ghosh and Ghosh, 1976; Sailakshmeshwari *et al.* (1985) [15] have also reported about obtaining CR-K after 6th to 7th extractions with HNO_3 in soils of Nagaland and Andhra Pradesh.

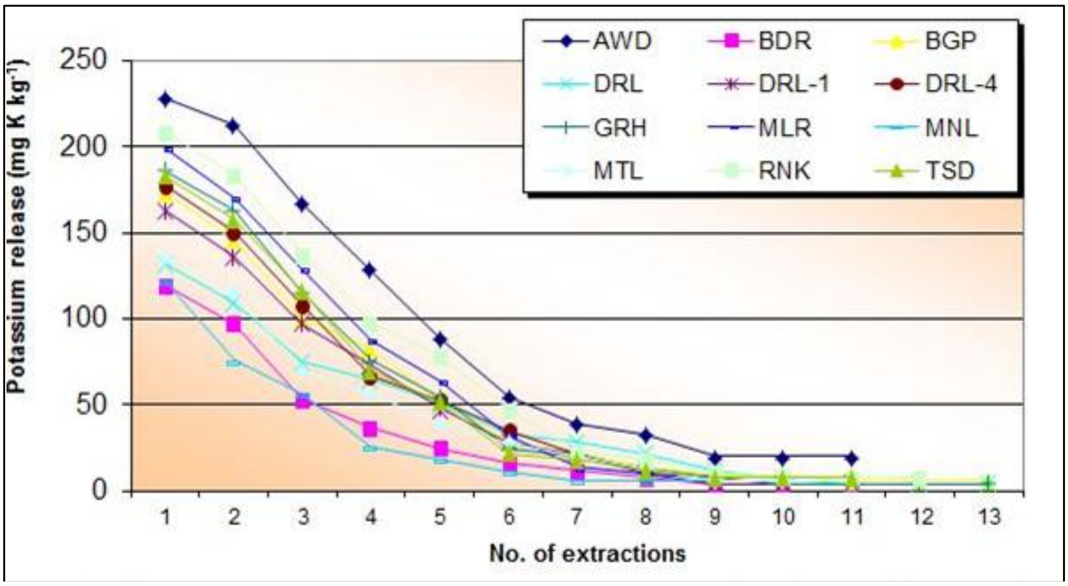

Fig 1: potassium release characteristic in sub-surface soil of black soil series of Kavalur sub watershed of Koppal district

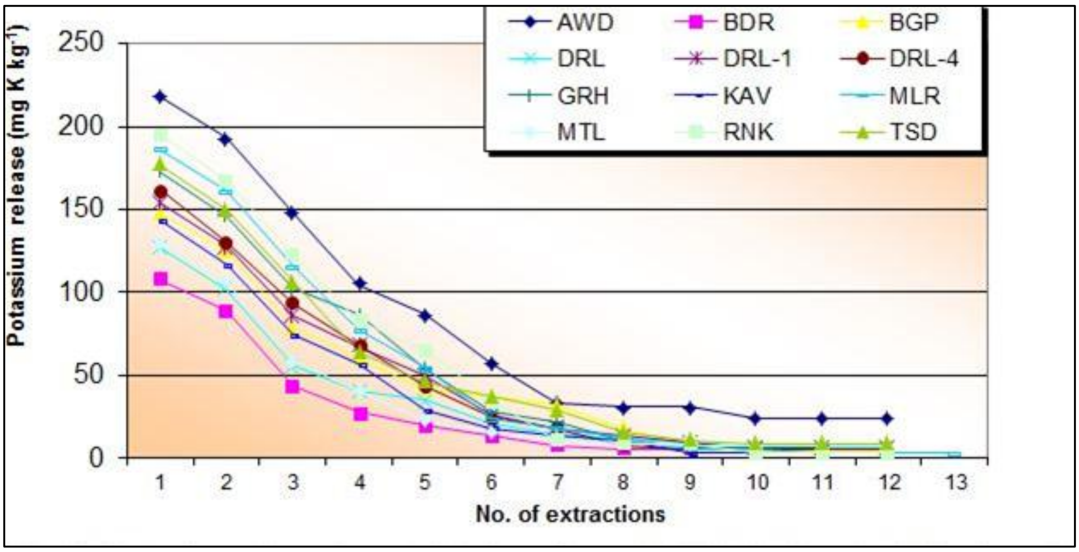

Fig 2: potassium release characteristic in surface soils of black soil series of Kavalur sub watershed of Koppal district

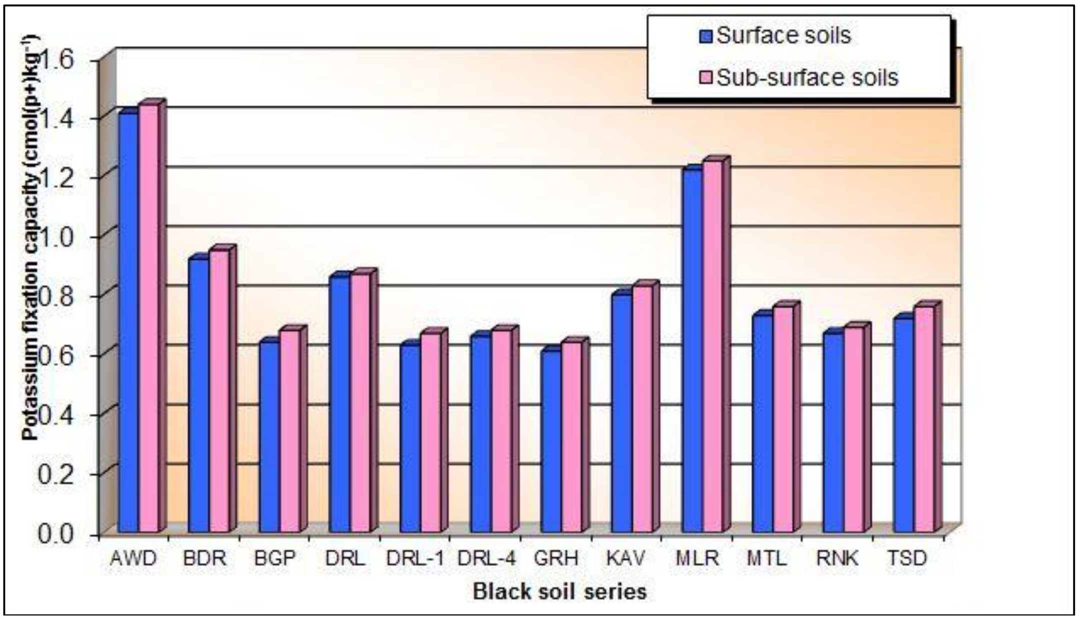

Fig 3: Potassium fixation capacity in black soil series of Kavalur sub watershed of Koppal district

Conclusion

Fixation capacity of potassium by soils depended mainly upon the K-saturation of the exchange complex and the total clay content of soil. Major portion of cumulative K from all most all the treatment combinations was released by the fourth extraction with the reagent *viz*., 1*N* HNO_3. The soil series containing relatively higher amounts of non-exchangeable K recorded higher amounts of cumulative K than those with lower amounts of non-exchangeable K. Step K of soils was also found to have the same behavior in different soil series as observed in the case of cumulative release K. Constant rate K was encountered by 11th or 12th extraction indicating K releasing power of soils for a long period of time.

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