Potassium Release Characteristics in Relation to Soil Properties in Soils of Major Cropping Systems in Kurnool District

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Abstract: Sixty representative surface soil samples (0-15 cm) were collected from 5 major cropping systems (rice-rice, fallow-bengal gram, groundnut-groundnut, maize-maize, rice-maize/mustard) covering 13 mandals in Kurnool district of Andhra Pradesh. Based on K status, the potassium releasing characteristics of thirty soils were studied by repeated extractions with boiling 1*N* HNO_3 and their relationship between soil properties and different forms of potassium. The soils were moderately coarse to fine in texture and neutral to slightly alkaline, non-saline and non-calcareous. Potassium release characteristics and different forms of potassium were highest in maize-maize cropping system and the lowest in groundnut-groundnut cropping system. Most of the soils had lower step-K and cumulative-K. The K release parameters were positively and significantly correlated with non-exchangeable form of soil K, pH, O.C, CEC and clay fraction of soil and negatively correlated with sand fraction of soil.

Keywords: *Step-K, constant-K, cumulative-K, potassium forms*

Introduction

Potassium is one of the major and essential plant nutrients that have an instrumental role in plant nutrition and physiology. Plants feed not only from exchangeable K but also from non-exchangeable K, which mainly consists of K trapped in the interlayer of non-expanding clay minerals. Major contribution of non-exchangeable K by crop removal was reported particularly in soils under continuous cropping without K application (Srinivasa Rao *et al.* 2007). In absence of external K supply, most of the crop K needs are met from soil reserve sources of K. Boiling 1*N* HNO_3 extracts some of non-exchangeable K by breakdown of primary and secondary minerals (Patiram and Prasad 1983).Crop uptake and response to potassium show a good correlation with boiling 1*N* HNO_3 extractable K of soils (Sivaprasad 2014). Haylock (1956) introduced the concept of step-K and constant rate-K as measures of plant utilizable non-exchangeable K release in a soil. Step-K provides the estimates of K- availability from non-exchangeable sources and more available part of the mineral lattice sources. Constant rate-K serves as a empirical guide to long term K supplying parameters of soil.The dynamics of potassium in soil depends on the magnitude of equilibrium among various forms and mainly governed by the physico-chemical properties of soil (Lalitha and Dakshinamoorthy 2014). Hence the present investigation has been undertaken to study the potassium release characteristics of thirty soils in major cropping systems in relation to soil properties and different forms of potassium in Kurnool district of Andhra Pradesh.

Material and methods

Surface soils were collected from 60 locations in major cropping systems of Kurnool district of Andhra Pradesh and 30 samples were screened for present investigation based on K status. The soil samples were air-dried and passed through the 2mm sieve and preserved in a polyethylene bag for laboratory analysis. The particle-size analysis was carried out by Bouyoucous hydrometer method (Piper 1966). The pH and EC were determined in 1:2 soils: water suspension using pH meter and EC meter (Jackson 1973).The free $CaCO_3$ content was determined as per procedure described by Piper (1966). Water soluble potassium was determined in 1:5 soil: water extract, after 5 minutes of shaking (Kanwar and Grewal 1966). The available potassium was

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determined by neutral one normal ammonium acetate extract (1:5 soil:extractant), after 5 minutes shaking as described by Jackson (1973). The exchangeable potassium was obtained as a difference of the available and water soluble potassium. The fixed form of potassium was determined by boiling with 1 *N* HNO_3 (1:10 soil: acid ratio) for 10 minutes (Wood and Deturk 1941). The non-exchangeable potassium was obtained by deducting the available potassium from fixed potassium contents. Potassium release parameters in terms of different K release parameters *viz.,* step K, constant rate K and cumulative K of soils were derived as per the procedure developed by Heylock (1956) and modified by Maclean (1961) using 1*N* HNO_3 as extractant. This method involved removal of exchangeable K by soaking 5g of soil in 50 ml of 0.01 *N* HNO_3 overnight and leaching the soil with 10 ml portion of 0.01*N* HNO_3 (4-5 times), then the soil sample was boiled with 1*N* HNO_3 (1:10 soil: 1*N* HNO_3) exactly for 10 min and then cooled and filtered. Extractions were carried out with the same reagent to a stage where the release of K from soil continues at more or less constant rate. By subtracting the amount of constant rate K from the amount of K released in each step of successive extraction, the amount of relatively easily soluble from of K (step-K) was computed. The total amount of K released in all the extractions was taken as cumulative K. Correlation coefficient of potassium release parameters with different forms of K, and soil properties were carried out as per the procedures outlined by Panse and Sukhatme (1978).

Results and Discussion

The pH of soils varied from 6.9 in red soils of Yembavi in groundnut-groundnut cropping system to 8.4 in black soils of Bheemunipadu of rice-mustard cropping system (Table1). The electrical conductivity of soils ranged from 0.10 dSm^{-1}in red soils of Yembavi of groundnut-groundnut cropping system to 0.69 dSm^{-1} in black soils of Venkateswarapuram in fallow-bengal gram cropping system (Table 1). The texture of the soils varied from moderately coarse to fine to sandy loam and clay (Table 2).

The highest mean water soluble form of potassium was observed in rice-mustard/maize cropping system (17 mg kg^{-1}) followed by maize-maize cropping system (15 mg kg^{-1}), rice-rice cropping system (13 mg kg^{-1}), fallow-bengal gram system (9 mg kg^{-1}) and lowest in groundnut-groundnut cropping system (7 mg kg^{-1}). Mean available form of potassium was the highest in maize-maize cropping system (357 mg kg^{-1}) followed by fallow- bengal gram cropping system (292 mg kg^{-1}), rice-mustard/maize cropping system (269 mg kg^{-1}), rice-rice cropping system (181 mg kg^{-1}) and lowest in groundnut-groundnut cropping system (152 mg kg^{-1}). The highest mean exchangeable form of potassium was observed in maize-maize cropping system (342 mg kg^{-1}) followed by fallow- bengal gram system (283 mg kg^{-1}), rice-mustard/maize cropping system (253 mg kg^{-1}), rice-rice cropping system (168 mg kg^{-1}) and lowest in groundnut-groundnut cropping system (145mg kg^{-1}) (Table 2). The highest mean non-exchangeable form of potassium was observed in maize-maize cropping system (429 mg kg^{-1}) followed by fallow- bengal gram cropping system (347 mg kg^{-1}), rice-mustard/maize cropping system (322 mg kg^{-1}), rice-rice cropping system (237 mg kg^{-1}) and lowest in groundnut-groundnut cropping system (206 $mgkg^{-1}$).

The highest fixed form mean of potassium was observed in maize-maize cropping system (770 mg kg^{-1}) followed by fallow- bengal gram system (639 mg kg^{-1}), rice-mustard/maize cropping system (534 mg kg^{-1}), rice-rice cropping system (416 mg kg^{-1}) and the lowest in groundnut-groundnut cropping system (358mg kg^{-1}). All forms of potassium were the highest in maize-maize cropping system and lowest in groundnut-groundnut cropping system (Table 3) mainly due to fertilizer management practices. High levels of fertilizers were applied in maize-maize cropping system compared to groundnut-groundnut cropping system. Low levels of water soluble and exchangeable forms of potassium in all the soils of different cropping systems might be due to continuous cropping without addition of potassium or inadequate application of potassium (Santhy *etal.* 1998).Water soluble, available and exchangeable forms were low compared to non-exchangeable and fixed forms, because major portion of soil potassium exists as part of mineral structure in fixed or non-exchangeable form and a small fraction as water soluble and exchangeable form

Table 1. Properties of initial soils

S. No	Village name	Cropping system	Clay (%)	Silt (%)	Sand (%)	pH	EC (dS m^{-1})	$CaCO_3$ (%)	O.C (%)	C.E.C cmol (p^+) kg^{-1}
1	RARS,Nandyal	Rice-rice	43.0	14.3	42.5	8.2	0.22	0.68	0.47	27.76
2	Battaluru	Rice-rice	20.8	36.8	42.4	8.1	0.46	0.49	0.43	20.31
3	Nallagatla	Rice-rice	24.8	34.8	40.4	7.9	0.20	2.27	0.44	19.42
4	Kaminenipalli	Rice-rice	15.8	27.8	56.4	7.5	0.18	0.22	0.27	14.21
5	Yerragudidinna	Rice-rice	21.8	31.8	46.4	7.4	0.21	2.72	0.36	15.4
6	M.C. farm	Rice-rice	19.0	12.3	68.6	7.3	0.32	1.58	0.46	13.36
7	Srinagaram	Maize-maize	31.8	12.3	56.5	8.3	0.68	0.22	0.44	29.91
8	Tamadapalli	Maize-maize	29.8	42.2	38.2	8.1	0.27	0.22	0.55	22.82
9	Velpanuru	Maize-maize	35.0	2.36	62.5	8.2	0.20	1.36	0.46	25.69
10	Mahanandi	Maize-maize	22.8	40.8	36.4	7.9	0.20	1.59	0.45	21.31
11	Nallakalva	Maize-maize	13.8	23.8	62.4	7.2	0.17	2.04	0.34	17.43
12	M.C.farm	Maize-maize	9.8	25.8	64.4	7.4	0.18	1.45	0.48	17.65
13	Kanala	Rice-mustard	22.8	40.8	40.4	8.2	0.19	0.90	0.39	23.76
14	Bhemunipadu	Rice-mustard	31.0	10.3	58.5	8.4	0.55	2.07	0.33	19.92
15	Bollavaram	Rice-maize	31.2	12.3	56.5	7.9	0.30	2.32	0.41	20.32
16	Rythunagaram	Rice-mustard	16.8	24.8	58.4	7.3	0.57	0.45	0.43	26.65
17	Ayyavarikoduru	Rice-maize	31.0	4.36	64.5	7.2	0.22	1.81	0.44	17.21
18	Gajulapalli	Rice-maize	29.8	8.3	62.5	7.5	0.10	2.12	0.41	18.21
19	RARS,Nandyal	Fallow-bengal gram	23.8	31.8	44.4	8.1	0.68	2.04	0.50	24.91
20	Venkateswarwpuram	Fallow-bengal gram	22.8	44.8	32.4	8.3	0.69	1.68	0.51	26.41
21	Neravada	Fallow-bengal gram	16.8	39.2	44	8.0	0.17	1.13	0.48	21.29
22	Balapanuru	Fallow-bengal gram	21.8	37.8	40.4	8.2	0.26	1.81	0.47	22.82
23	Kouluru	Fallow-bengal gram	23.8	39.8	36.4	8.0	0.21	0.90	0.53	28.61
24	Boyirevula	Fallow-bengal gram	19.8	2.8	77.4	7.8	0.31	0.18	0.34	18.32
25	M.C.farm	Groundnut-groundnut	8.8	14.8	76.4	7.4	0.11.	0.45	0.27	16.82
26	Shankarapalli	Groundnut-groundnut	8.2	10.8	80.4	7.1	0.19	0.90	0.27	15.75
27	Muddaram	Groundnut-groundnut	8.8	11.8	76.4	7.2	0.14	0.22	0.21	13.15
28	Balapuram	Groundnut-groundnut	13.8	23.8	62.4	7.1	0.26	5.21	0.42	18.69
29	Balapalapalli	Groundnut-groundnut	6.8	10.8	82.4	7.2	0.66	0.22	0.34	13.03
30	Yembavi	Groundnut-groundnut	8.8	10.8	80.4	6.9	0.10	2.72	0.24	14.81
	Mean		**21.16**	**22.83**	**56.38**		**0.31**	**2.13**	**0.40**	**20.20**

Table 2. Different forms of potassium (mg kg^{-1} soil) in different cropping systems of soils

S.No	Village name	Water soluble K	Available K	Exchange able K	Non-Exchangeable K	Fixed K
				mg kg^{-1} soil		
1	RARS,Nandyal	12	225	213	345	570
2	Battaluru	12	190	178	196	387
3	Nallagatla	16	183	167	260	428
4	Kaminenipalli	11	82	71	128	210
5	Yerragudidinna	10	130	120	139	270
6	M.C. farm	17	279	262	356	635
	Mean	**13**	**181**	**168**	**237**	**416**
7	Srinagaram	22	779	757	807	1586
8	Tamadapalli	15	338	323	392	730
9	Velpanuru	14	355	341	497	852
10	Mahanandi	13	215	202	237	416
11	Nallakalva	09	131	122	199	331
12	M.C.farm	20	326	306	377	703
	Mean	**15**	**357**	**342**	**429**	**770**
13	Kanala	9	246	237	364	364
14	Bhemunipadu	13	131	118	137	268
15	Rythunagaram	21	357	336	401	758
16	Bollavaram	11	371	360	448	820
17	Ayyavarikoduru	18	206	188	222	328
18	Gajulapalli	28	305	277	363	668
	Mean	**17**	**269**	**253**	**322**	**534**
19	RARS,Nandyal	08	261	253	362	623
20	Venkateswarwpuram	11	362	351	491	853
21	Neravada	6	210	204	242	453
22	Balapanuru	10	326	316	353	680
23	Kouluru	13	475	462	484	960
24	Boyirevula	6	117	112	150	267
	Mean	**9**	**292**	**283**	**347**	**639**
25	M.C.farm	8	201	193	220	421
26	Shankarapalli	10	203	193	232	436
27	Muddaram	6	71	65	117	189
28	Balapuram	7	301	294	440	741
29	Balapalapalli	8	58	50	110	166
30	Yembavi	5	81	76	117	193
	Mean	**7**	**152**	**145**	**206**	**358**

in soil. Different forms of potassium in the soils have the following order; fixed K > non-exchangeable K > available K> exchangeable K > water soluble K. Similar reports were also observed by Sawarkar *et al.* (2013).

Release of non-exchangeable K by repeated extractions with boiling 1N HNO_3

Potassium release was rapid in first four extractions in most of the soils followed by a gradual decrease which reached to a constant value in either 7th or 8th extraction. Mean extractable1*N* HNO_3 potassium was higher in maize-maize cropping system followed by fallow- bengal gram cropping system, rice-mustard cropping system, rice-rice cropping system and lowest in groundnut-groundnut cropping system in all the extractions of the soil (Table 3).

Constant-K

The highest mean constant rate-K was observed in rice-rice cropping system (25 mg kg^{-1}) followed by maize-

Table 3. Release of non-exchangeable K (mg kg^{-1}) in cropping system

S.No	Village name	Number of extractions							
		1st	2nd	3rd	4th	5th	6th	7th	8th
1	RARS,Nandyal	420	228	156	102	66	40	22	22
2	Battaluru	372	190	126	85	45	26	26	
3	Nallagatla	404	210	103	89	56	31	31	
4	Kaminenipalli	202	110	80	52	19	19		
5	Yerragudidinna	302	156	85	45	23	23		
6	M.C. farm	489	260	140	85	52	29	29	
	Mean	**365**	**192**	**115**	**76**	**44**	**28**	**27**	**22**
7	Srinagaram	752	406	226	138	69	35	35	
8	Tamadapalli	556	260	192	96	48	20	20	
9	Velpanuru	445	250	175	105	65	35	30	30
10	Mahanandi	420	210	140	96	56	15	10	10
11	Nallakalva	291	156	85	47	23	23		
12	M.C.farm	563	293	201	110	85	55	27	27
	Mean	**505**	**263**	**170**	**99**	**58**	**31**	**24**	**22**
13	Kanala	502	286	162	92	57	35	12	12
14	Bhemunipadu	245	135	75	50	30	10	10	
15	Rythunagaram	340	220	190	120	82	50	30	30
16	Bollavaram	710	323	178	106	89	55	32	32
17	Ayyavarikoduru	375	210	170	105	18	30	30	
18	Gajulapalli	260	155	95	75	50	15	15	
	Mean	**405**	**222**	**145**	**91**	**54**	**33**	**20**	**21**
19	RARS,Nandyal	385	**210**	125	95	75	35	15	15
20	Venkateswarwpuram	525	273	185	97	69	36	15	15
21	Neravada	302	166	109	82	44	21	21	
22	Balapanuru	400	225	155	95	63	32	18	18
23	Kouluru	680	340	180	110	65	32	**17**	17
24	Boyirevula	265	145	95	65	25	18	18	
	Mean	**426**	**227**	**142**	**91**	**57**	**29**	**17**	**16**
25	M.C.farm	352	192	98	56	22	22		
26	Shankarapalli	322	166	86	48	21	21		
27	Muddaram	130	78	46	22	12	12		
28	Balapuram	402	256	198	93	54	21	21	
29	Balapalapalli	110	87	46	31	10	10		
30	Yembavi	172	95	68	36	13	13		
	Mean	**248**	**146**	**90**	**48**	**22**	**17**	**21**	

maize cropping system (24 mg kg^{-1}), rice-maize cropping system (22 mg kg^{-1}), rice-mustard cropping system (18 mg kg^{-1}), fallow- bengal -gram cropping system (17mg kg^{-1}) and groundnut-groundnut cropping system (12 mg kg^{-1}) (Table 4).

Metson (1969) reported that soils having constant rate K more than 0.2 (c mol (p^+) kg^{-1}) or 78 mg kg^{-1} will have sufficient constant K value indicating existence of dynamic equilibrium among different forms. All the soils had less constant rate K (Table 4) than critical value of constant rate K as suggested by Metson (1969). It indicates that these soils had low supplying powers to plants and also that non-exchangeable potassium pool could slowly replenish the water soluble and exchangeable K fractions by affecting the crop growth to considerable extent.

Step K

The highest mean step-K was observed in maize-maize cropping system (945 mg kg^{-1}) followed by rice-mustard cropping system (939 mg kg^{-1}), fallow- bengal gram cropping system (866 mg kg^{-1}), rice-maize cropping system (744 mg kg^{-1}), rice-rice cropping system (670 mg kg^{-1}) and groundnut-groundnut cropping system (472 mg kg^{-1}) (Table 4). The higher step-K was observed in soils of maize –maize cropping system due to the result of change in potassium equilibrium in forward direction (Krishna Kumari and Khera 1992). More the amount of step-K more will be the plant utilizable non-exchangeable K under stress condition. The reserve potassium involved in replenishment process of available K during the growing period is mainly released from clay and micas of fine textured soil (Datta and Sastry 1993). Some of the soils had lower step-K value than critical value as 1.5 (C mol (p^+) kg^{-1}) or 585 mg kg^{-1} as suggested by Hunsigi and Srivastava (1981). In general the soils having lower step-K values may show more response to applied potassium than soils having higher step-K values.

Table 4. K release parameters (mg kg^{-1}) in different cropping systems

S.No	Cropping system	Constant K	Step- K	Cumulative K
	Rice-rice cropping system			
1	RARS,Nandyal	22	880	1056
2	Battaluru	26	688	870
3	Nallagatla	31	707	924
4	Kaminenipalli	19	368	482
5	Yerragudidinna	23	496	634
6	M.C. farm	29	881	1084
	Mean	**25**	**670**	**842**
	Maize-maize cropping system			
7	Srinagaram	35	1416	1661
8	Tamadapalli	20	1032	1192
9	Velpanuru	30	895	1135
10	Mahanandi	10	877	957
11	Nallakalva	23	487	625
12	M.C.farm, maize	27	964	1180
	Mean	**24**	**945**	**1125**
	Rice-mustard cropping system			
13	Kanala	12	1062	1158
14	Bhemunipadu	10	485	555
15	Rythunagaram	32	1269	1525
	Mean	**18**	**939**	**1079**

S.No	Cropping system	Constant K	Step- K	Cumulative K
	Rice-maize cropping system			
16	Bollavaram	20	882	1042
17	Ayyavarikoduru	30	790	1000
18	Gajulapalli	15	560	665
	Mean	**22**	**744**	**902**
	Fallow-bengal gram cropping system			
19	RARS,Nandyal	15	835	985
20	Venkateswarwpuram	15	1095	1215
21	Neravada	21	598	745
22	Balapanuru	18	862	1006
23	Kouluru	17	1305	1441
24	Boyirevula	18	505	631
	Mean	**17**	**866**	**1004**
	Groundnut-groundnut cropping system			
25	M.C.farm,groundnut	22	610	742
26	Shankarapalli	21	538	664
27	Muddaram	12	228	300
28	Balapuram	21	898	1045
29	Balapalapalli	10	234	294
30	Yembavi	13	319	317
	Mean	**12**	**472**	**573**

Table 5. Correlation co-efficient (r) between potassium release parameters and different forms of K

	pH	EC	$CaCO_3$	O.C	C.E.C	clay	silt	sand
Con-K	0.01	-0.09	0.05	0.26	0.13	0.28	-0.21	0.02
Step-K	0.51**	0.21	0.04	0.74**	0.75**	0.49**	0.31***	-0.53
Cum-K	0.49**	0.19	0.04	0.74**	0.73**	0.50**	0.26	-0.50

Table 6. Correlation co-efficient (r) between potassium release parameters and soil characteristics

	Water soluble K	Available K	Exchangeable K	Non - exchangeable K	Fixed K
Con-K	0.493**	0.410*	0.399*	0.385*	0.409*
step-K	0.485**	0.864**	0.863**	0.866**	0.831**
Cum –K	0.521**	0.862**	0.860**	0.864**	0.834**

* Significant at 0.05 per cent level
**Significant at 0.01 per cent level
*** Significant at 0.1 per cent level

Cumulative K release

Mean cumulative-K release was the highest in maize-maize cropping system (1125 mg kg^{-1}) followed by rice-mustard cropping system (1079 mg kg^{-1}), fallow-bengal-gram cropping system (1004 mg kg^{-1}), rice-maize cropping system (902 mg kg^{-1}), rice-rice cropping system (842 mg kg^{-1}) and groundnut-groundnut cropping system (573 mg $kg^{-1)}$. Srinivasa Rao *et al.,* (2007) reported that cumulative K was higher if it exceeds more than 1500 mg kg^{-1} of soil with 1*N* HNO_3. Lower amounts of cumulative K (less than 1500 mg kg^{-1}) was observed in all soils except soils of Srinagaram and Rythunagaram villages. Lower cumulative K and continuous cropping would lead to depletion of soil K reserves and result in K deficiency (Table 4). Finally, it can be concluded that by considering all the potassium releasing parameter variations within a group or within a cropping system of soils was due to variation in texture of soils. Similar results were obtained by Dhillon and Dhillon (1994), Srinivasa Rao *et al.* (2007).

The data presented in the table 5 indicated that among various potassium release parameters step-K and cumulative-K showed positive and significant correlation with all forms of potassium but maximum positive and significant correlation with non-exchangeable K. K release parameters also positively and significantly correlated with water soluble form indicating that equilibrium exists in different forms of potassium. Due to dynamic equilibrium, depletion in a given K-form is likely to shift the equilibrium in the direction to replenish it.

The potassium release parameters *i.e.* step-K and cumulative-K showed positive and significant correlation with pH, organic carbon, CEC, and clay and negative correlation with sand **(Table 6)**. All the K release parameters were positively correlated with the clay fraction of soil indicating that potassium was mainly extracted from the clay fraction in soil. Negative relationship of the K release parameters with sand fraction might be due to the indirect effect of the negative relationship between sand and clay content in soil. Similar results were also reported by Das and Jena (2010) in some Alfisols of Orissa.

Conclusion

All investigated soils recorded less cumulative-K except two. Lower cumulative K and continuous cropping would lead to depletion of soil K reserves and result in K deficiency. The K release parameters were positively and significantly correlated with water soluble form of soil potassium indicating that equilibrium exists in different forms of potassium. The potassium release parameters *i.e.* step-K and cumulative-K showed positive and significant correlation with pH, organic carbon, CEC, and clay and negative correlation with sand.

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