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Dynamics of Soil Potassium Under Prominent Cropping Systems of Nellore District, Andhra Pradesh, India

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Abstract: In the present investigation five prominent cropping systems of Nellore district of Andhra Pradesh *viz.*, paddy-paddy, fallow-blackgram, fallow-bengalgram, fallow-paddy and groundnut-paddy were selected to study dynamics of soil potassium. The highest mean available K was recorded under groundnut-paddy cropping sequence (249.36 mg kg^{-1}) in surface soils, while in sub-surface soils under fallow-blackgram cropping sequence (164.48 mg kg^{-1}). Highest mean water-soluble K was found under paddy-paddy cropping sequence both in surface (33.67 mg kg^{-1}) and sub-surface soils (23.87 mg kg^{-1}). Highest mean exchangeable K was recorded under groundnut-paddy cropping sequence (230.20 mg kg) in surface soils, while in sub-surface soils under fallow-blackgram cropping sequence (152.96 mg kg^{-1}). Highest mean non-exchangeable K was found under groundnut-paddy cropping sequence at both surface (642.70 mg kg^{-1}) and sub-surface soils (668.54 mg kg^{-1}). Highest mean lattice K and total K were observed under paddy-paddy cropping sequence at both surface (30044.48 and 30572 mg kg^{-1}, respectively) and sub-surface soils (18671.76 and 19158 mg kg, respectively). The forms of potassium were positively correlated among themselves indicating dynamic equilibrium among different forms K in soils under prominent cropping systems of Nellore district.

Potassium (K) is third most important plant nutrient after nitrogen and phosphorus which plays vital roles in osmoregulation, cation-anion balance, water balance and transport of assimilates in plants (Epstein and Bloom 2005). It also acknowledged as master cation because it occurs in the highest concentration in the plant cell sap. The preference of farmers in our country for nitrogen, phosphorus over potassium is reflected in the skewed N: P_2O_5: K_2O consumption ratio, which was 6.6:2.6:1 in 2018-19 over the golden ratio of 4:2:1 (FAI 2019). Phytoavailability K in various forms influenced by the equilibrium and kinetic reaction between forms of soil-K, moisture content, temperature and bivalent cations concentration in solution and on the exchanger phase. Potassium in soil exists in four forms, namely water soluble K, exchangeable K, non-exchangeable K and lattice K, which are in dynamic equilibrium that controls its phytoavailability. Bioavailable pool of K comprises of water soluble K and the exchangeable K held on negatively charged exchange surfaces in the soil. The major portion of the reserve of available K in soil is contributed by non-exchangeable K and a primary factor in determining soil K fertility (Wang et al 2016). The potassium fractions exist in dynamic equilibrium among them which govern the K nutrition in crops and are important for the growth of higher plants and microbes. Impaired nutrient consumption largely affects the status and forms of potassium distribution thereby deteriorating soil fertility and decline in crop productivity. Imbalanced K fertilization for long periods of time may adversely affect the K release rates in a soil, ultimately lowering its K supplying capacity to plants. Such low K application affects the soil's K-fertility status over long period (Das et al 2018, 2019). The proficiency on various forms potassium helps to understand conditions admiring of potassium availability to growing crops in the soil and also for potassium management in order to determine the long-term sustainability of cropping systems. Therefore, there is a need to assess potassium fractions in the soil is imperative to optimize crop productivity and cropping systems through sound fertilizer recommendations. Present study was undertaken to study the distribution of potassium forms under different cropping sequences in Nellore district of Andhra Pradesh.

MATERIAL AND METHODS

An investigation was carried out in S. V. Agricultural College, Tirupati, during 2019 to assess the fractions of soil potassium from prominent cropping systems of Sri Potti Sri Ramalu (S.P.S.R) Nellore district of Andhra Pradesh. The district is situated at Geographical Co-ordination of 14° 26' 33.3564'' N and 79° 59' 11.2488'' E. Nellore is located at 18m above mean sea level. Nellore's climate is classified as tropical. The average temperature is 28.3°C. Mean annual precipitation 33.7 inch per year. Five soil samples from each cropping system at 0-15cm and 15-30cm depths were collected from farmers' fields' *viz.,* paddy-paddy, fallow-blackgram, fallow-bengalgram, fallow-paddy and groundnut-paddy cropping sequences during 2018-19. These are prominent cropping sequences which were followed by the Nellore farmers since 10-12 years continuously on the same fields. Soil sample were air-dried, ground in a wooden pestle with mortar and passed through a 2-mm stainless steel sieve and used for determining various soil properties by following standard procedures (Table 1). Simple correlation coefficients ('r') were also worked out for relationships among potassium forms using Statistical Package for Social Sciences (SPSS) software.

RESULTS AND DISCUSSION

Soil properties: The pH indicated that all the soils were alkaline in reaction. The soils from all cropping sequences were calcareous in nature and non-saline. The soil texture ranged from sandy clay loam to clay (Table 2).

Available K (Avl-K): The mean available K content of surface soils varied from 63.4 mg kg^{-1} in fallow-paddy cropping system to 249 mg kg^{-1} in groundnut- paddy cropping sequence, respectively and contribution of available K to total K ranged from 0.260 to 1.34 per cent. In sub-surface soils average available K content varied from 43.3 mg kg^{-1} in fallow-paddy cropping system to 164 mg kg^{-1} in fallow-blackgram cropping sequence (Table 3). The contribution of available K to total K ranged from 0.350 to 2.53 per cent. The highest available potassium was in soils of groundnut-paddy cropping system in surface soils might be due to application of potassic fertilizers to surface layers only and in sub-surface soils available potassium was higher in fallow-blackgram cropping system, which might be due to its removal by crops from the surface soil and leaching and accumulation in the subsurface soil containing higher amount of clay and organic matter (Kundu et al 2014) and lowest available potassium was in fallow-paddy cropping system in both surface and sub-surface soils, which might be due to higher uptake of K resulted in depletion of K (Elbaalawy et al 2016). The highest available potassium was observed in surface soils than in sub-surface soils in all cropping systems, which might be attributed to more intense weathering, release of K from organic residues, application of K fertilizers and upward translocation of potassium from lower depth along with capillary raise of ground water (Rao et al 2017).

Water soluble K (WS-K): The mean water-soluble K content

Table 1. Analytical methods followed during chemical analysis

Properties	Methodology	Reference
Available Potassium	Neutral *1N* NH_4OAC extraction	Jackson (1973)
Forms of Potassium	Flame photometry	
Water Soluble K	1:5 Soil water suspension	Jackson (1973)
Exchangeable K	Available K – Water soluble K	
Non-exchangeable K	Boiling *1N* Nitric acid extraction	Wood and De Turk (1941)
Lattice K	Total K – (Available K + Non-exchangeable K)	Wiklander (1954)
Total K	HF – $HClO_4$ extraction	Pratt (1965)

Table 2. Physico-chemical properties of soils under cropping systems of Nellore district

Cropping systems	Textural class	pH		EC (dSm^{-1})		CEC [c mol p(+) kg^{-1}]
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm
Paddy – Paddy	Sandy clay loam	7.42 (7.31-7.60)	7.23 (7.09-7.52)	0.028 (0.013-0.039)	0.026 (0.013-0037)	6.39 (6.0-6.73)
Fallow-Blackgram	Clay loam	8.18 (8.08-8.31)	8.24 (8.13-8.31)	0.012 (0.01-0.014)	0.015 (0.012-0.019)	13.60 (13.10-14.62)
Fallow – Bengalgram	Clay	7.93 (7.82-8.11)	7.73 (7.12-7.97)	0.029 (0.023-0.037)	0.025 (0.013-0.038)	33.06 (31.31-36.34)
Fallow-Paddy	Sandy clay loam	7.54 (7.40-7.74)	8.36 (8.23-8.55)	0.092 (0.077-0.110)	0.033 (0.022-0.055)	21.77 (20.72-22.11)
Groundnut - Paddy	Sandy clay loam	7.69 (7.54-7.84)	7.74 (7.55-7.87)	0.028 (0.016-0.038)	0.032 (0.026-0.049)	10.70 (9.88-11.44)

Figures in parentheses represents range

of surface soils varied from 6.23 mg kg^{-1} in fallow-paddy cropping system to 33.67 mg kg^{-1} in paddy-paddy cropping. The water soluble K contributed least to total K and ranged from 0.030 to 0.130. In sub-surface soils water soluble K content varied from 5.61 mg kg^{-1} in fallow-paddy cropping system to 23.8 mg kg^{-1} in paddy-paddy cropping sequence (Table 3). Contribution of water soluble K to total K ranged from 0.070 to 0.220 per cent. The highest water soluble K was observed in soils of paddy-paddy cropping system in both surface and sub-surface soils, which might be due to high dose of K fertilizers were applied to paddy in both seasons while lowest water soluble K was observed in fallow-paddy cropping system at both depths, which might be due to which might be due to non application of K fertilizers to first crop. The highest water soluble K was observed in surface soils than in sub-surface soils in all cropping systems, which might be attributed to accumulation of potassium applied through fertilizers in the surface layers. Similar results were reported under rice - wheat cropping system by Jassal et al (2012) and Kumari and Nisha (2014).

Exchangeable K (EX-K): The exchangeable K content of surface soils varied from 57.19 mg kg^{-1} in fallow-paddy cropping system to 230 mg kg^{-1} in groundnut - paddy cropping sequence. The exchangeable K contribution to total K ranged from 0.240 to 2.02 per cent. In sub-surface soils exchangeable K content varied from 37.78 mg kg^{-1} in fallow-paddy cropping system to 152 mg kg^{-1} in fallow-blackgram cropping sequence (Table 3). This fraction contributed 0.230 to 2.31 per cent to total K. The highest exchangeable K was observed in soils of groundnut - paddy cropping system and fallow-blackgram cropping system in surface and sub-surface soils, respectively which might be due to application of fertilizers during cultivation of these crops and lowest exchangeable K was in fallow-paddy cropping system in both surface and sub-surface soils, which might be due to non application of potassic fertilizers to the first crop. The data further revealed that highest exchangeable K was observed in surface soils than in sub-surface soils in all cropping systems, which might be attributed to capillary action of K ions from lower layer to the upper layer and paved for the crop uptake (Divya et al 2016).

Non-exchangeable K (NEX-K): The non-exchangeable K content of surface soils varied from 231 mg kg^{-1} in groundnut-paddy cropping system to 588 mg kg^{-1} in fallow-blackgram cropping sequence with mean values of 265 and 551 mg kg^{-1}, respectively. This fraction contribution to total K ranged from 1.29 to 4.98 per cent. In sub-surface soils non-exchangeable K content varied from 359 mg kg^{-1} in fallow-paddy cropping system to 454 mg kg^{-1} in paddy - paddy cropping sequence with mean of 387 and 418 mg kg^{-1}, respectively (Table 3). Per

Table 3. Distribution of different forms of potassium under prominent cropping systems

Cropping Systems	Available K (mg kg^{-1})		Water soluble K (mg kg^{-1})		Exchangeable K (mg kg^{-1})		Non-exchangeable K (mg kg^{-1})		Lattice K (mg kg^{-1})		Total K (mg kg^{-1})	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	0-15 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Paddy-Paddy	132.89 (109.55-145.70)	68.00 (61.05-77.35)	33.67 (26.75-38.35)	23.87 (17.95-28.15)	99.22 (82.80-107.35)	44.13 (40.60-49.20)	394.63 (364.60-433.70)	418.24 (390.45-454.65)	30044.48 (25743.80-33370.60)	18671.76 (15832.80-20383.50)	30572 (26230-33950)	19158 (16290-20910)
Fallow-Blackgram	238.20 (201.35-275.95)	164.48 (149.70-175.50)	14.34 (9.95-20.05)	11.52 (10.20-14.00)	223.86 (191.40-255.90)	152.96 (139.10-161.50)	551.44 (508.15-588.85)	397.12 (362.55-432.40)	10278.36 (9260.50-11254.30)	7340.40 (7031.00-7660.10)	11068 (9970-12090)	7902 (7600-8210)
Fallow-Bengalgram	145.18 (124.30-171.20)	128.71 (116.75-139.00)	7.61 (5.95-9.45)	6.35 (5.60-8.05)	137.57 (118.35-161.75)	122.36 (111.00-130.95)	532.24 (510.10-548.00)	407.55 (374.00-423.00)	14660.58 (13214.50-16480.80)	6263.74 (4645.40-7278.00)	15338 (13870-17200)	6800 (5150-7840)
Fallow-Paddy	63.42 (55.10-73.80)	43.39 (38.80-46.85)	6.23 (5.45-7.45)	5.61 (5.25-5.95)	57.19 (49.30-66.35)	37.78 (33.45-41.00)	349.24 (279.45-396.20)	387.25 (359.55-407.95)	23709.34 (20918.30-25050.00)	8133.36 (7479.50-8586.80)	24122 (21320-25520)	8564 (7930-9010)
Groundnut – Paddy	249.36 (204.55-78.85)	158.26 (145.45-173.35)	19.16 (14.95-22.80)	13.65 (13.10-15.10)	230.20 (189.60-256.05)	144.61 (132.35-159.80)	265.95 (231.45-281.55)	395.86 (361.30-446.85)	18146.69 (15314.50-19365.80)	5709.88 (4701.10-6662.80)	18662 (16280-20120)	6264 (5210-7210)

Figures in parentheses represents range

cent contribution of non-exchangeable K to total K varied between 2.18 and 5.99. The highest non-exchangeable K was in soils of fallow-blackgram cropping system and paddy-paddy cropping system in surface and sub-surface soils, respectively which might be due to presence of higher clay and organic matter content and lowest non-exchangeable K was observed in fallow-paddy cropping system at both depths, which might be due to crops are grown successively with less potassium application to soil as a result mining of K takes place (Sharma et al 2016). The highest non-exchangeable K was in sub-surface soils than in surface soils in all cropping systems, except in fallow-blackgram cropping system and fallow-bengalgram cropping system which might be attributed to release of potassium reserve pool to compensate the loss of available potassium by plant uptake and may be due to adsorption and fixation of K removed from surface through leaching. Similar findings were obtained by earlier researchers (Kundu et al 2014, Saini and Grewal 2014, Divya et al 2016).

Lattice K: The lattice K content of surface soils varied from 9260 mg kg^{-1} in fallow -blackgram cropping system to 33370 mg kg^{-1} in paddy-paddy cropping sequence with mean values of 10278 and 30044 mg kg^{-1}, respectively. Major portion of total K comprised of this fraction and contribution varied from 92.8 to 98.2 per cent. In sub-surface soils lattice K content varied from 4645 mg kg^{-1} in fallow-bengalgram cropping system to 20383 mg kg^{-1} in paddy-paddy cropping sequence with mean values of 6263.74 and 18671 mg kg^{-1}, respectively (Table 3). Per cent contribution of lattice K to total K ranged from 92.8 to 97.4. The highest lattice K was observed in soils of fallow-paddy and paddy-paddy cropping system in surface and sub-surface soils, respectively which might be due to type and nature of parent material present and degree of weathering however, lowest lattice K was in fallow-blackgram cropping system and fallow-blackgram cropping system in surface and sub-surface soils, respectively. The highest lattice K was observed in surface soils than in sub-surface soils in all cropping systems, which might be attributed to higher K-bearing minerals in their lattice structure (Anil et al 2009).

Total K: The total K content of surface soils varied from 9970 mg kg^{-1} in fallow - blackgram cropping system to 33950 mg kg^{-1} in paddy-paddy cropping sequence with mean values of 11068 and 30572 mg kg^{-1}, respectively. In sub-surface soils total K content varied from 5150 mg kg^{-1} in fallow-bengalgram cropping system to 20910 mg kg^{-1} in paddy-paddy cropping sequence with mean 6800 and 19158 mg kg^{-1}, respectively (Table 3). The highest total K was observed in soils of paddy-paddy cropping system in both surface and sub-surface soils, which might be due to high concentration of lattice K (Abdul et al 2013) and lowest was observed in fallow-blackgram cropping system and groundnut - paddy cropping system in surface and sub-surface soils, respectively. The highest total K was observed in surface soils than in sub-surface soils in all cropping systems which might be due to the presence of considerable amount of potassium bearing minerals as a reserve from external application to satisfy out the crop demand (Divya et al 2016).

Table 4. Correlation among different forms of potassium in surface soils under prominent cropping systems

	Avl-K	WS-K	EX-K	NEX-K	Lattice-K	Total-K
Avl-K	1					
WS-K	0.262	1				
EX-K	0.990**	0.123	1			
NEX-K	0.875**	-0.023	0.903**	1		
Lattice-K	-0.547**	0.574**	-0.646**	-0.642**	1	
Total-K	-0.531**	0.585**	-0.632**	-0.628**	0.999**	1

** Correlation is significant at the 0.01 level (2-tailed).* Correlation is significant at the 0.05 level (2-tailed)

Table 5. Correlation among different forms of potassium in sub-surface soils under prominent cropping systems

	Avl-K	WS-K	EX-K	NEX-K	Lattice-K	Total-K
Avl-K	1					
WS-K	0.304	1				
EX-K	0.982**	0.120	1			
NEX-K	0.433*	-0.090	0.469*	1		
Lattice-K	-0.539**	0.478*	-0.656**	-0.290	1	
Total-K	-0.526**	0.485*	-0.643**	-0.266	0.999**	1

** Correlation is significant at the 0.01 level (2-tailed).* Correlation is significant at the 0.05 level (2-tailed)

Correlation among forms of potassium under different cropping systems: The highest positive degree of significant correlation was between lattice K and total K followed by available K with exchangeable K, exchangeable K with non-exchangeable K, available K with non-exchangeable K, water soluble K with total K and lattice K at both surface (Table 4) and sub-surface soils (Table 5). Similar results were corroborated by earlier researchers (Dhakad et al 2017, Elbaalawy et al 2016, Kundu et al 2014 and Saini and Grewal 2014). All the forms of potassium at both depths were correlated with each other revealing the existence of dynamic equilibrium among them.

CONCLUSION

Soil K fractions in all cropping systems were found in the order of lattice K > non-exchangeable K > available K > exchangeable K > water soluble K. In S.P.S.R Nellore district, under rainfed conditions all the forms of potassium were highest in fallow-blackgram cropping system followed by fallow-bengalgram cropping system. Under irrigated conditions all the forms of potassium were highest in groundnut-paddy cropping system followed by paddy-paddy cropping system and fallow-paddy cropping system. At both soil layers different forms of K were positively and significantly correlated with each other in soils indicating dynamic equilibrium among different forms.

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