Environment and Ecology 40 (2) : 425—431, April—June 2022
ISSN 0970-0420

Dynamics of Soil Potassium under Different Cropping Systems in Y.S.R Kadapa District of Andhra Pradesh

Charankumar G.R., V. Munaswamy,
T. Giridhara Krishna, D. Subramanyam

Received 12 February 2022, Accepted 24 March 2022, Published on 26 April 2022

ABSTRACT

The present study was conducted to study the dynamics of soil potassium under different cropping systems in Y.S.R Kadapa district, Andhra Pradesh. Results indicated that the available K content varied from 73.65 mg kg^{-1} to 282.80 mg kg^{-1} and from 51.30 mg kg^{-1} to 160.90 mg kg^{-1}, water soluble K from 5.5 mg kg^{-1} to 43.30 mg kg^{-1} and from 5.05 mg kg^{-1} to 17.25 mg kg^{-1}, exchangeable K from 68.10 mg kg^{-1} to 254.10 mg kg^{-1} and from 43.70 mg kg^{-1} to 144.05 mg kg^{-1}, non-exchangeable K from 309.95 mg kg^{-1} to 970.35 mg kg^{-1} and from 238.80 mg kg^{-1} to 623.00 mg kg^{-1}, lattice K from 11498.10 mg kg^{-1} to 23326.60 mg kg^{-1} and from 6460.20 mg kg^{-1} to 35828.20 mg kg^{-1} and total K from 11920 mg kg^{-1} to 24190 mg kg^{-1} and from 6990 mg kg^{-1} to 33330 mg kg^{-1} in surface and sub-surface soils, respectively under different cropping systems. Available K ranged from 0.58 to 1.33% and 0.11 to 1.58%, water soluble K 0.07 to 0.18% and 0.03 to 0.18%, exchangeable K 0.44 to 1.20% and 0.14 to 1.44%, non-exchangeable K 2.33 to 5.08% and 1.15 to 6.26% and lattice K 94.00 to 97.08% and 92.16 to 98.68% in surface and sub-surface soils of total potassium, respectively under different cropping systems. All the forms of K were correlated with each other revealing the existence of dynamic equilibrium among them.

Keywords Forms of potassium, K dynamics, Cropping systems.

INTRODUCTION

Soil fertility is declining mostly as a result of excessive nutrient loss and insufficient nutrient addition via fertilizers and manures. This circumstance puts Indian agriculture under pressure to produce more food on dwindling arable land. Thus, intensive cropping is necessary and future food production will grow increasingly reliant on mineral fertilizers, which have become indispensable for assuring adequate food production and reversing soil productivity reduction due to nutrient depletion.

Potassium is third most important plant nutrient which is absorbed by plant is in larger amount than

Charankumar G.R.*
PhD Scholar, Dept. of Soil Science and Agricultural Chemistry, SVPUAT, Meerut, UP 250110
V. Munaswamy
Professor, Dept. of Soil Science and Agricultural Chemistry, S.V. Agricultural College, Tirupati, A.P. 517502
T. Giridhara Krishna
Registrar, Acharya NG Ranga Agricultural University, Lam, Guntur, A.P. 522034
D. Subramanyam
Professor, Dept. of Agronomy, S.V. Agricultural College, Tirupati, A.P. 517502
Email: charangrkumar@gmail.com
*Corresponding author

any other mineral element except nitrogen and it is one of the three main pillars of balanced fertilizer use, along with nitrogen and phosphorus. The potassium is mobile in plant, unlike other major nutrients, it's not the integral part of the plant component but, it plays a vital role in enzyme activity, acts as a catalyst for carbohydrate and nitrogen metabolism, translocation of assimilates, synthesis of proteins, as well as formation, break down and translocation of starch, maintains water balance, agronomic productivity and sustainability (Mangel 1985).

The results of long term fertilizer experiments in India revealed that by growing crops without K for longer periods lead the mining of soil native K and there by declining available K. The availability of K in soil is governed by both organic and inorganic forms and prevailing soil chemical environment. Availability of native K to plants is largely regulated by the dynamic equilibrium existing between different forms of K viz., water soluble-K, which is taken up by the plants and microbes directly (Sparks 2000); exchangeable-K, held by negative charges on clay particles, humic substances and it is exchangeable with cations and readily available to plants, non-exchangeable or fixed-K, which is trapped between the layers of dioctahedral and trioctahedral micas, vermiculites and it is sparingly available to plants (Sparks and Huang 1985) and while lattice –K or mineral or structural K, an integral part of primary K bearing minerals which compraises 98% of total K. Knowledge on these different potassium fractions in soils is essential for potassium management to determine long term sustainability of cropping systems. To formulate sound fertilizer recommendation, potassium supplying capacity of soil is essential. This will depend not only on the available K content of soil, but also knowledge on different forms of K and their relationship among themselves is required. Keeping this in view, the present study was under taken to assess dynamics of soil potassium under different cropping systems in Y.S.R Kadapa district of Andhra Pradesh.

MATERIALS AND METHODS

The present study was carried out in Y.S.R Kadapa district of Andhra Pradesh. The district is situated at Geographical Co-ordination of 13° 43' to 15° 14' of Northern latitude and 77° 55' to 79° 29' of the Eastern longitude. This district lies in river basin of Pennar. The district is classified as drought Prone area due to scanty and uneven distribution of rain fall. The annual rainfall of the district is 700 mm. Five soil samples from each cropping system at 0-15 cm and 15-30 cm depths were collected from the Y.S.R. district viz., fallow – bengalgram, sunflower – sesame, paddy – paddy, groundnut mono cropping and groundnut – groundnut cropping sequences during 2018-19. Soil sample were air-dried, ground in a wooden pestle with mortar and passed through a 2mm stainless steel sieve and used for determining various soil properties by following standard procedures.

Water soluble K was extracted by shaking the soil water suspension in the ratio of 1:5 for 5 min then filtered and K was determined (Jackson 1973) and available K was extracted with neutral normal ammonium acetate with 1:5 soil solution ratio and shaking for five minutes (Hanway and Heidel 1952). The exchangeable K was obtained by subtracting water-soluble K from available K. The non-exchangeable K was estimated by following the method as described by Wood and De Turk (1941). Lattice-K was calculated from the difference between total K and the sum of NH_4OAc-K and nonexchangeable K (Wiklander 1954). Total K in soil was estimated by HF-$HClO_4$ digestion method using platinum crucibles as outlined by Pratt (1965). Potassium in all the extracts was estimated flame photometrically. The statistical analysis was done to understand correlation among different forms of potassium and with soil properties

RESULTS AND DISCUSSION

Distribution of different forms of potassium under different cropping systems tabulated in Table 1.

Available K

The available K content of surface soils varied from 73.65 mg kg^{-1} in sunflower-sesame cropping system to 282.80 mg kg^{-1} in paddy-paddy cropping sequence with mean values of 84.55 and 262.80 mg kg^{-1} and

Table 1. Distribution of different forms of potassium under different cropping systems.

Cropping systems		Available K (mg kg⁻¹) 0-15 cm	Available K (mg kg⁻¹) 15-30 cm	Water soluble K (mg kg⁻¹) 0-15 cm	Water soluble K (mg kg⁻¹) 15-30 cm	Exchangeable K (mg kg⁻¹) 0-15 cm	Exchangeable K (mg kg⁻¹) 15-30 cm
	Min	146.75	113.80	12.65	5.95	134.10	107.85
1. Fallow – Bengalgram	Max	191.20	145.70	23.05	14.00	168.15	131.70
	Mean	162.69	130.86	18.59	10.26	144.10	120.60
	Min	73.65	62.60	5.55	5.05	68.10	57.55
2. Sunflower – Sesame	Max	92.35	79.80	11.85	8.05	80.50	71.75
	Mean	84.55	72.31	9.52	6.63	75.03	65.68
	Min	246.70	141.60	23.55	8.15	223.15	133.45
3. Paddy – Paddy	Max	282.80	160.90	28.70	16.85	254.10	144.05
	Mean	262.84	151.73	26.07	12.89	236.77	138.84
	Min	134.30	51.30	13.00	7.60	114.60	43.70
4. Groundnut monocropping	Max	156.50	60.50	21.90	10.35	134.60	50.75
	Mean	140.19	55.08	18.04	9.01	122.15	46.07
	Min	122.80	112.45	30.15	10.45	92.65	102.00
5. Groundnut – Groundnut	Max	152.05	133.95	43.30	17.25	108.75	116.70
	Mean	136.16	123.63	37.24	14.35	98.92	109.28

Table 1. Continue

Cropping systems		Non-exchangeable K (mg kg⁻¹) 0-15 cm	Non-exchangeable K (mg kg⁻¹) 15-30 cm	Lattice K (mg kg⁻¹) 0-15 cm	Lattice K (mg kg⁻¹) 15-30 cm	Total K (mg kg⁻¹) 0-15 cm	Total K (mg kg⁻¹) 15-30 cm
	Min	835.20	356.40	13813.80	17932.80	14810	18500
1. Fallow – Bengalgram	Max	970.35	453.40	19462.40	23837.90	20470	24340
	Mean	896.49	424.44	16596.82	20862.70	17656	21418
	Min	309.95	238.80	11498.10	9976.10	11920	9990
2. Sunflower – Sesame	Max	352.95	309.30	17699.60	10610.90	15200	11000
	Mean	337.35	275.13	14038.10	10138.56	14460	10486
	Min	752.80	571.50	16772.10	8286.90	17810	9000
3. Paddy – Paddy	Max	825.35	623.00	20697.80	9306.10	21700	10090
	Mean	791.70	602.53	18653.46	8891.74	19708	9646
	Min	568.60	357.20	17191.40	28501.50	17980	28910
4. Groundnut monocropping	Max	644.30	381.75	21238.10	35828.20	22010	36270
	Mean	617.39	370.04	18940.42	31708.88	19698	32134
	Min	668.90	417.35	18448.30	6460.20	18910	6990
5. Groundnut – Groundnut	Max	730.10	549.75	23326.60	7606.30	24190	8290
	Mean	699.52	490.79	20116.32	7219.58	20952	7834

their per cent contribution to total K 0.58 and 1.33, respectively. In sub-surface soils available K content varied from 51.30 mg kg-^{1} in groundnut monocropping system to 160.90 mg kg-^{1} in paddy-paddy cropping sequence with mean values of 55.08 and 151.73 mg kg-^{1} and their per cent contribution to total K 0.17 and 1.58, respectively.

The highest available potassium was observed in soils of paddy-paddy cropping system in both surface and sub-surface soils, which might be due to continuous application of potassic fertilizers to both the crops and lowest available potassium was recorded in sunflower-sesame cropping system and groundnut monocropping system in surface and sub-surface soils, respectively which might be due to continuous less application of potassic fertilizers application than crop needed or imbalanced fertilization in crop nutrition caused mining of its native pools. Similar results reported by Katkar *et al*. (2011). The data further revealed that highest available potassium was observed in surface soils than in sub-surface soils in all cropping systems, which might be attributed to presence of vegetation or upward translocation of K from lower layers through capillary rise or ground water as reported by Lungmuana *et al*. (2014).

Water soluble K

The water soluble K content of surface soils varied from 5.5 mg kg^{-1} in sunflower-sesame cropping system to 43.30 mg kg^{-1} in groundnut -groundnut cropping sequence with mean values of 9.52 and 37.24 mg kg^{-1} and their per cent contribution to total K 0.07 and 0.18, respectively. In sub-surface soils water soluble K content varied from 5.05 mg kg^{-1} in sunflower-sesame cropping system to 17.25 mg kg^{-1} in groundnut -groundnut cropping sequence with mean values of 6.63 and 14.35 mg kg^{-1} and their per cent contribution to total K 0.03 and 0.18, respectively.

The highest water soluble K was observed in soils of groundnut-groundnut cropping system in surface and sub-surface soils, which might be due to addition of fertilizers, presence of potassium bearing minerals while lowest water soluble K was observed in sunflower-sesame cropping system at both depths, which might be due to exhaustive nature of crops. The data further revealed that highest water soluble K was observed in surface soils than in sub-surface soils in all cropping systems, which might be due to capillary movement of potassium from lower depth to upper portion reported by Hebsur and Gali (2011).

Exchangeable K

The exchangeable K content of surface soils varied from 68.10 mg kg^{-1} in sunflower-sesame cropping system to 254.10 mg kg^{-1} in paddy-paddy cropping sequence with mean values of 75.03 and 236.77 mg kg^{-1} and their per cent contribution to total K 0.52 and 1.20, respectively. In sub-surface soils exchangeable K content varied from 43.70 mg kg^{-1} in groundnut monocropping system to 144.05 mg kg^{-1} in paddy-paddy cropping sequence with mean values of 46.07 and 138.84 mg kg^{-1} and their per cent contribution to total K 0.14 and 1.44, respectively.

The highest exchangeable 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 or due to the fact that soils contain relatively higher clay per cent which offered more exchangeable sites for K. these results were in agreement with (Hebsur and Gali 2011) and lowest exchangeable K was observed in sunflower-sesame cropping system and groundnut monocropping system in surface and sub-surface soils respectively might be due to exhaustive nature of sunflower and sesame crops and low utilization under groundnut monocropping system or due to non replenishment of K from the other (Rao *et al*. 2013). The results further revealed that highest exchangeable K was observed in surface soils than in sub-surface soils in all cropping systems.

Non-exchangeable K

The non-exchangeable K content of surface soils varied from 309.95 mg kg^{-1} in sunflower-sesame cropping system to 970.35 mg kg^{-1} in fallow-bengalgram cropping sequence with mean values of 337.35 and 896.49 mg kg^{-1} and their per cent contribution to total K 2.33 and 5.08, respectively. In sub-surface soils non-exchangeable K content varied from 238.80 mg kg^{-1} in sunflower-sesame cropping system to 623.00 mg kg^{-1} in paddy-paddy cropping sequence with mean values of 275.13 and 602.53 mg kg^{-1} and their per cent contribution to total K 1.15 and 6.26, respectively.

The highest non-exchangeable K was observed in soils of fallow-bengalgram cropping system and paddy-paddy in surface and sub-surface soils, respectively which might be due to higher percentage of clay in these soils and lowest non-exchangeable K was observed in sunflower-sesame cropping system at both depths, which might be due to continuous cropping with less application of K fertilizers may decreased K content in these cropping systems. The data further revealed that highest non-exchangeable K was observed in surface soils than in sub-surface soils in all cropping systems. These findings were in agreement with Mazumdar *et al.* 2014.

Lattice K

The lattice K content of surface soils varied from

11498.10 mg kg-[1] in sunflower-sesame cropping system to 23326.60 mg kg-[1] in groundnut-groundnut cropping sequence with mean values of 14038.10 and 20116.32 mg kg-[1] and their per cent contribution to total K 94.00 and 97.08, respectively. In sub-surface soils lattice K content varied from 6460.20 mg kg-[1] in groundnut-groundnut cropping system to 35828.20 mg kg-[1] in groundnut monocropping sequence with mean values of 7219.58 and 31708.88 mg kg-[1] and their per cent contribution to total K 92.18 and 98.68, respectively.

The highest lattice K was observed in soils of groundnut-groundnut cropping system and groundnut monocropping system in surface and sub-surface soils, respectively. These findings were in accordance with Sawarkar *et al*. 2013 which might be due to these soils were derived from potassic bearing minerals however, lowest lattice K was observed in sunflower-sesame cropping system and groundnut-groundnut cropping system in surface and sub-surface soils, respectively. The data further revealed that highest lattice K was observed in surface soils than in sub-surface soils in all cropping systems, except in fallow-bengalgram cropping system and groundnut monocropping system which might be attributed to increase in finer fractions of soil particles at lower depth.

Total K

The total K content of surface soils varied from 11920 mg kg-[1] in sunflower-sesame cropping system to 24190 mg kg-[1] in groundnut-groundnut cropping sequence with mean values of 14460 and 20952 mg kg-[1], respectively. In sub-surface soils total K content varied from 6990 mg kg-[1] in groundnut-groundnut cropping system to 33330 mg kg-[1] in groundnut monocropping sequence with mean values of 7834 and 32134 mg kg-[1], respectively.

The highest total K was observed in soils of groundnut-groundnut cropping system and groundnut monocropping system in surface and sub-surface soils, respectively which might be due to predominance of potassium bearing primary minerals and lowest total K was observed in sunflower-sesame cropping system and groundnut-groundnut cropping system in surface and sub-surface soils, respectively. The data further revealed that highest total K was observed in surface soils than in sub-surface soils in all cropping systems, except in fallow-bengalgram cropping system and groundnut monocropping system. Similar results were reported by Mazumdar *et al.* (2014).

Correlation among forms of potassium

Correlation between forms of potassium with soil properties in surface and sub-surface soils, tabulated in Tables 2-3, respectively.

In surface soils available K was positively and significantly correlated with water soluble K (r = 0.416*), exchangeable K (r = 0.987**) and non-exchangeable K (r = 0.791**). Similar results were obtained by Swamanna *et al.* (2015) under rice growing soils of Kurnool district of A.P. Available K also showed positive and significant correlation with total K (r = 0.421*). Water soluble K was highly and significantly correlated with available K (r = 0.416*) and non-exchangeable K (r = 0.744**). Similar results were reported by Kundu *et al*. (2014) under inceptisols of Janjgir district of Chhattisgarh.

Table 2. Correlation among different forms of potassium in surface soils under different cropping systems. **. Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). N = 25**.**

	Avl K	WS-K	EX-K	NEX-K	Lattice-K	Total-K
Avl K	1					
WS-K	0.416*	1				
EX-K	0.987**	0.266	1			
NEX-K	0.791**	0.744**	0.708**	1		
Lattice-K	0.377	0.665**	0.283	0.705**	1	
Total-K	0.421*	0.682**	0.327	0.741**	0.999**	1

Table 3. Correlation among different forms of potassium in sub-surface soils under different cropping systems. **Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).
N=25. Avl K= Available K, WS-K= Water soluble K, EX-K= Exchangeable K,
NEX-K= Non-exchangeable K.

	Avl.-K	WS-K	EX-K	NEX-K	Lattice-K	Total-K
Avl. K	1					
WS-K	0.245	1				
EX-K	0.766**	0.062	1			
NEX-K	0.943**	0.486*	0.701**	1		
Lattice-K	-0.482*	-0.223	-0.350	-0.472*	1	
Total-K	-0.472*	-0.219	-0.343	-0.462*	0.999**	1

Water soluble K also showed positive and significant correlation with lattice K (r = 0.665**) and total K (r = 0.682**). These observations were in accordance to the results reported by Dhakad *et al*. (2017), Saini and Grewal (2014). Exchangeable K was highly and significantly correlated with available K (r = 0.987**) and non-exchangeable K (r = 0.708**) indicating that decline in the level of exchangeable K is replenished by the release of non-exchangeable K. Similar results reported by Elbaalawy *et al.* (2016). Swamanna *et al. (*2015). Non-exchangeable K was highly and significantly correlated with available K (r = 0.791**), water soluble K (r = 744**) and exchangeable K (r = 0.708**). Similar observations were made by Dhakad *et al*. (2017), Lakaria *et al*. (2012), Prasad *et al. (*2010), Swamanna *et al.* (2015). Non-exchangeable K positively and significantly correlated with lattice K (r = 705**) and total K (r = 0.741**). Lattice K was highly and significantly correlated with water soluble K (r = 0.665**) non-exchangeable K (r = 0.705**) and total K (r = 0.999**). Total K was highly and significantly correlated with available K (r = 0.421*), water soluble K (r = 0.682**), non-exchangeable K (r = 0.741**) and lattice K (r = 0.999**). Similar results were obtained by Dhakad *et al*. (2017) indicating that these relationships confirmed that availability of exchangeable, nonexchangeable and total potassium could significantly determine potentially available potassium in these soils.

All the forms of K showed a positive trend of correlation among themselves largely corroborating the well-known concept of existence of a dynamic equilibrium among different forms of K present in soil through which K supply to the roots of crop plants are directly or indirectly ensured as reported Lungmuana *et al.* 2014.

In sub-surface soils available K was highly and significantly correlated with exchangeable K (r = 0.766**) and non-exchangeable K (r = 0.943**). Similar observations were made by Jatav and Dewangan (2012). Whereas available K also showed negative and significant correlation with lattice K (r = -0.482*) and total K (r = -0.472*). Water soluble K was positively and significantly correlated with non-exchangeable K (r = 0.486*). Exchangeable K was highly and significantly correlated with available K (r = 0.766**) and non-exchangeable K (r = 0.701*). Similar results reported by Jatav and Dewangan (2012) Rajeevana and Kavitha (2017). Non-exchangeable K was highly and significantly correlated with available K (r = 0.943**), water soluble K (r = 0.486*) and exchangeable K (r = 0.701**). Similar observations were made by Rajeevana and Dewangan (2017). Non-exchangeable K was negatively and significantly correlated with lattice K (r = -0.472*) and total K (r = -0.462*). Lattice K was highly and significantly correlated with total K (r = 0.999**) while it was negatively and significantly correlated with available K (r = -0.482*) and non-exchangeable K (r = -0.472*). Total K was highly and significantly correlated with lattice K (r = 0.999**) but it was negatively and significantly correlated with available K (r = -0.472*) and non-exchangeable K (r = -0.462*).

CONCLUSION

Based on these results, it is therefore suggested that K removal by the crop must be supplemented to sustain the soil fertility either by K application or by crop straw incorporation to the soil. Soil K fractions varied with depth and cropping sequences. Soil K fractions were found in the order lattice K > non-exchangeable K > available K > exchangeable K > water soluble K. Under irrigated conditions all the forms of potassium were highest in paddy-paddy cropping system followed by groundnut-groundnut cropping system and sunflower-sesame cropping system while under rainfed conditions all the forms of potassium were highest in fallow-bengalgram cropping system followed by groundnut monocropping system. The results and the methodology adopted in the present study will be useful in assessing forms of K under different cropping systems. These results would not only useful for the study area, but also in other cropping systems across the globe.

REFERENCES

Dhakad H, Yadav SS, Jamra S, Arya V, Sharma K, Gaur D (2017) Status and distribution of different forms of potassium in soils of Gwalior district (MP) *Int J Che Stu* 5: 161-164.

Elbaalawy AM, Benbi DK, Benipal DS (2016) Potassium forms in relation to clay mineralogy other soil properties in different agro-ecological sub-regions of Northern India. *Agric Res J* 53: 200-206.

Hanway JJ, Heidel H (1952) Soil analysis methods, as used in Iowa State. *College Soil Testing Laboratory, Iowa, Agriculture* 57: 1-31.

Hebsur NS, Gali SK (2011) Potassium dynamics in soils under different cropping systems of Karnataka. Soil Science Research North Karnataka, 76th Annual Convention Indian Society of Soil Science, pp 85-89.

Jackson ML (1973) Soil Chemical Analysis. Prentice Hall of India (P) Ltd, New Delhi.

Jatav GK, Dewangan DK (2012) Distribution of various forms of potassium in inceptisol of Baloda block in Janjgir district of Chhattisgarh. *An Asi J Soil Sci* 7: 231-234.

Katkar RN, Sonune BA, Kadu PR (2011) Long-term effect of fertilization on soil chemical and biological characteristics and productivity under sorghum-wheat system in Vertisol. *Ind J Agric Sci* 81: 734–739.

Kundu MC, Hazra GC, Biswas PK, Mondal S, Ghosh GK (2014) Forms distribution of potassium in some soils of Hooghly district of West Bengal. *J Crop Weed* 10: 31-37.

Lakaria BJ, Behera SK, Singh D (2012) Different forms of potassium and their contributions toward potassium uptake under long-term maize (*Zea mays* L.) – wheat (*Triticum aestivum* L.) – cowpea (*Vigna unguiculata* L.) rotation on an inceptisol. *Commun Soil Sci Pl Anal* 43: 936–947.

Lungmuana, Bose A, Ghosh I, Ghosh SK, Patra PK (2014) Distribution variation of potassium in rice growing soils of red laterite zone of West Bengal. *J Ind Soc Soil Sci* 62: 84-87.

Mangel K (1985) Dynamics availability of major nutrients in soils. *Adv Soil Sci* 2: 65-131.

Mazumdar S, Kundu DK, Ghosh D, Saha AR, Majumdar B, Ghorai AK (2014) Effect of long-term application of inorganic fertilizers and organic manure on yield, potassium uptake and distribution of potassium fractions in the new gangetic alluvial soil under jute-rice-wheat cropping system. *Int J Agric Food Sci Tech* 4: 297-306.

Prasad RK, Vipinkumar, Prasad B, Singh AP (2010) Long-term effect of crop residues zinc fertilizer on crop yield, nutrient uptake fertility build up under rice wheat cropping system in Calciorthents. *J Ind Soc Soil Sci* 58: 205-211.

Pratt PF (1965) Potassium In: Black CA ed.Methods of Soil Analysis Part American Society of Agronomy Inc, Madison, Wisconsin.

Rajeevana I, Kavitha P (2017) Potassium forms in relation with k uptake studies in soils of different cropping systems in Kurnool district. *Int J Pure Appl Biosci* 6: 175-183.

Rao KN, Yeledhalli NA, Channal HT (2013) Soil potassium dynamics under intensive rice cropping in TBP command area of north Karnataka. *An Asi J Soil Sci* 8: 319-324.

Saini J, Grewal KS (214) Vertical distribution of different forms of potassium their relationship with different soil properties in some Haryana soil under different crop rotation. *Adv Pl Agric Res* 1: 48–52.

Sawarkar SD, Khamparia NK, Thakur R, Dewda MS, Singh M (2013) Effect of long-term application of inorganic fertilizers organic manure on yield, potassium uptake profile distribution of potassium fractions in Vertisol under soybean-wheat cropping system. *J Ind Soc Soil Sci* 61:94-98.

Sparks DL (2000) Bioavailability of soil potassium, In: ME Sumner (ed). Handbook of Soil Science, CRC Press, Boca Raton.

Sparks DL, Huang PM (1985) Physical chemistry of soil potassium. In. RD Munson (ed). Potassium in agriculture Ame Soci Agro.

Swamanna J, Kavitha P, Chari MS, Reddy MS (2015) Potassium dynamics in relation with soil properties in rice growing soils of Kurnool district, Andhra Pradesh. *Pra J Agric Sci* 1: 15-20.

Wiklander EA (1954) Forms of potassium in the soil Potassium Symposium International Potash Institute, Berne, Switzerland, pp 109-121.

Wood LK, De Turk EE (1941) The adsorption of potassium in soil in non-exchangeable forms. *Proce Soil Sci Socio Ame* 5:152-161.