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Soil potassium fractions as influenced by varying level of k mineral in an *Inceptisols.*

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Abstract
A field study was conducted to investigate the Assessment of potassium fractions as influenced by varying level of K mineral in an *Inceptisol* of Chhattisgarh plain at research cum instructional farm of IGKV, Raipur (C.G.) during the *Kharif* season of 2021. The result of investigation revealed that amount of potassium fractions *viz* available K, water soluble K and exchangeable K were higher in surface layer (0-15 cm) than that in subsurface soil depth (15-30 cm), (30-45 cm), (45-60 cm) and available, water soluble and exchangeable K was decreased with increase in soil depth. The non-exchangeable K and total K was found higher in subsurface layer than that in surface layer and increased with increase in depth. The application of RDF + K mineral @ 210 kg ha^{-1} recorded significantly higher amount of water soluble K (0-15 cm) (15-30 cm) and available K (0-15 cm). However both water soluble and available K at 15-30 cm 30-45 cm register at par values in all the treatments. The content of exchangeable K was found to be decreased with increasing soil depth. The exchangeable K was not affected significantly due to varying level of K mineral + RDF. The non-exchangeable and total K were found to be increased as soil depth increased and highest amount was recorded at 45-60 cm. There was no effect of application of RDF + K mineral on content of non-exchangeable and total K. The forms of potassium were in dynamic equilibrium and there amount follows the order non-exchangeable K > exchangeable K > available K > water soluble K >. All the forms of potassium show positive correlation with each other and available potassium is significantly and positively correlated with water soluble (r=0.612), exchangeable K (r=0.459) and non-exchangeable K (r=0.508).

Keywords: Potassium fractions, water soluble–K, exchangeable–K, non-exchangeable–K, total–K, sub-surface layer and correlation

Introduction
Potassium is a major constituent of the earth crust contained more in igneous rocks than the sedimentary rocks. Potassium comprises on an average of 2.6% of the earth crust, making it the seventh most abundant element and third most abundant mineral nutrient in the lithosphere. Among the major nutrients potassium (K) is known to be a wonder element due to its role in crop growth and its behaviour in the soil system. In soil, potassium can be found in a various forms including water soluble, exchangeable and non-exchangeable, lattice and total potassium. In a dynamic soil system, relative free mobility of K creates balance between the various K fractions. Soil minerals like mica and feldspar are the main sources of K accounting for 90 to 98 percent of total K, although their availability for plant use is quite low. Non-exchangeable potassium which is connected with the 2: 1 clay mineral and accounts for 1 to 10% of potassium in the soil is the second source of potassium. The third potassium source is exchangeable or readily available potassium which accounts for roughly 1% to 2% of total K and is present on cation exchange sites or in the soil solution (Rehm & Schmitt 2002) [11]. Potassium found in organic matter and in the soil microbial community provides a fourth potassium source. These provide extremely small amount of potassium which is essential for plant growth. These forms stay in a state of dynamic balance with one another. The readily available or water-soluble K has been observed to be a major contributing source in the early phases of crop growth, while non-exchangeable and exchangeable K contributes more in the latter stages (Subehia *et al.* 2003) [21]. The K status of the soil and the potential of K supply to plants are determined by the distribution of K forms and the equilibrium between them in the soil (Rubio and Gil-Sotres 1997 and Pavlov 2007) [12, 9].

Material and Methods
A field experiment was conducted during the *Kharif* season of 2021 at the Instructional Farm

of Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) located on NH6 in the eastern part of Raipur between 20 º 4' North latitude and 81 º39' East longitudes, at a height of 293 meters above mean sea level. The experiment was laid out in a randomised block design with rice variety Rajeshwari having 8 treatments which were randomised thrice *viz*. T1 (RDF + K mineral @ 210 kg ha^{-1}), T2 (RDF + K mineral @150 kg ha^{-1}), T3 (RDF + K mineral @ 120 kg ha^{-1}), T4 (RDF + K mineral @140 kg ha^{-1}), T5 (RDF + K mineral @110 kg ha^{-1}), T6 (RDF + K mineral @ 70 kg ha^{-1}), T7 (100% RDF Basal), T8 (100% N P,). The recommended dose of fertilizer (N, P_2O_5, K_2O) for rice was 100:60:40 kg/ha. Urea, single super phosphate and muriate of potash were applied as sources of fertilizer. Soil sample from 0-15 cm, 15-30 cm, 30-45 cm, 45-60 cm were collected from each plot separately and shade dried, samples were powered with wooden pestle and mortar and sieved through 2 mm sieve and analysed for available K, WSK, Exch-K, NEK and total K. Available K was determined by neutral normal ammonium acetate extraction method using flame photometer (Hanway and Heidel 1952) [5]. WSK was extracted by shaking the soils with water in 1:5 (soil: water) ratio for five minute. Exchangeable K was determined by using centrifugation and decantation technique (Black 1965) [1]. In a 50 mL centrifuge tube, 10 g of soil were placed and 25 mL ammonium acetate was added. The contents were then centrifuged for 10 minutes. Decant the supernatant into a 100 mL volumetric flask. Three more extractions were carried out in the same way. These extracts were diluted to 100 mL with ammonium acetate, well mixed, and potassium were estimated by using a flame photometer. Non-exchangeable K was determined by taking 2 g of soil in digestion tube then 20 mL of 1 N HNO_3 was added. The content was boiled at 113 ºC than potassium was estimated by flame photometer (Wood and De Turk 1941) [23].Total K was analysed by taking 1g soil in a digestion tube then 20 ml HNO_3 was added and heated at 130º C then 60 percent perchloric acid was added and placed the digestion tube in block digester and heated at 100 ºC for 15 minute then increase the temperature slowly to 180-200 ºC and digested the sample until dense white fumes of acid appear then coolled the solution and diluted to about 25 ml with warm distilled water and filter through Whatman filter paper No.42 in to 100 ml volumetric flask. Volume was makeup to 100 ml and 10ml aliquot of the digested extract was taken in 100 ml volumetric flask. Total K was estimated by flame photometer (Nayak *et al.* 2016) [7].

Table 1: Initial physico-chemical characteristics of soil

Properties	Value
pH	6.91
EC (dS/m)	0.24
Organic carbon (%)	0.56
Available Nitrogen (kg ha^{-1})	175.62
Available phosphorous (kg ha^{-1})	20.20
Available potassium (kg ha^{-1})	291.13
Available Zn	1.43
Available Cu	2.11
Available Mn	23.04
Available Fe	24.94

Result and Discussion

Depth wise distribution of potassium fractions

The distribution of water soluble potassium in different soil depths as influenced by graded levels of fertilizer and K-mineral application are presented in Table 2. Water soluble potassium content ranged from 16.01-20.89, 17.12-19.19, 15.23-16.81, 11.38-13.42 kg ha^{-1} in (0-15 cm), (15-30 cm), (30-45 cm), (45-60 cm) soil depths. The application of RDF + K mineral @ 210 kg ha^{-1} recorded significantly higher amount of water soluble potassium (20.89) in surface layer followed by application of RDF + K mineral @ 140 kg ha^{-1} (20.41 mg kg ha^{-1}) and the lowest level of water soluble K was recorded in control (16.01). The water soluble content was found significantly higher in T_1 (RDF + K mineral @ 210 kg ha^{-1}) than T_8 (control) and at par with T_2, T_3, T_4, T_5, T_6, T_7. The data showed that the amount of water soluble K was higher in the surface layer and gradually decreased downwards up to 60 cm depth in all the treatments. The results revealed that due to application of higher amount of K in T1 (RDF + K mineral @ 210 kg ha^{-1}) resulted significantly higher water soluble K in 0-15 and 15-30 cm soil depth. The increase in water soluble K could be attributed to an increase in K concentration in solution as a result of the increased rate of potassium application. Singh *et al.* 2002 [16] and Singh *et al.* 2006 [17]also reported that water soluble potassium content is higher in surface layer and it could be due to mineralization, cultivation practices and higher organic matter content and application of potassium bearing fertilizers and upward translocation of the element with capillary rise of ground water. Decrease in the water soluble form of K increasing soil depth was reported by Tomar *et al.* 2017 [22].

The content of available K was higher in surface layer and decreased downward up to 60 cm (Table 3). The status of available K ranged from 268.99 to 287.78, 273.67 to 283.97, 265.90 to 276.52, 262.24 to 267.80 kg ha^{-1} in (0-15 cm), (15-30 cm), (30-45 cm) and (45-60 cm) soil depths. Highest available K was recorded with application of RDF + K mineral @ 210 kg ha^{-1} (T1) which was significantly higher than control but at par with rest of the treatments (RDF + K mineral @ 70, 110, 140, 120, and 150 kg ha^{-1}) in all soil depths. The available K was higher at surface layer (0-15 cm) than that at subsurface layers (15-30 cm), (30-45 cm), (45-60 cm). The increase in soil available K followed by application of NPK and K mineral may be due to solubilizing action and certain organic acids produced during decomposition, as well as a greater capacity to hold K in the available form. Rajneesh *et al.* (2017) reported that the available potassium content was higher in surface soil layer (0-15 cm) as compared to lower depth. This could be due to a large portion of the K lost through soil leaching and it was taken up by the crop. Similar to this Hirekurbar *et al.* (2020) [6] and Patil *et al.* (2008) [8] observed that the surface soils had higher available K content, that could be believed to be due to more intense weathering of potash-bearing minerals, the application of K fertilizers and the upward translocation of K from lower depths due to capillary rise of ground water.

The result of depth wise distribution of exchangeable potassium are presented in table 4. The exchangeable potassium content in surface soil (0-15 cm) ranged from 838.4-883.8 kg ha^{-1} while that in (15-30 cm), (30-45 cm), (45-60 cm) soil depth ranged from 791.83-819.18, 759.63-787.19, 649.17-667.17 kg ha^{-1} respectively. The application of RDF+ K mineral @ 210 kg ha^{-1} (T1) recorded highest exchangeable K in all soil depth which was at par with rest of the treatments. The findings of present study revealed that exchangeable K decreased with increased depth of soil however there was no significant influence on content of exchangeable K due to application of graded K application through RDF and K-mineral. Sharma *et al.* (1994) [14] found that the concentration of exchangeable K was numerically lower in subsurface soil than in surface soil which may be due to more weathering, vegetation and supply of K from organic residue in the surface layer than in lower depth. Srinivasarao *et al*. (2007) [20] also reported lower levels of exchangeable K in *Inceptisols* and *Aridisols* despite higher content of K-rich mica in these soils which may be due to less mobility of K from the illite clay structure to the exchange complex because these minerals typically have a restrictive interlayer space that is selective for K ions, resulting in low desorption (Sparks and Huang 1985, Sparks 1987) [19, 18]. Sharma *et al.* 2009 [13] reported that the highest concentration of exchangeable K, under K fertilised plots in surface soil, could be attributed to the addition of K through plant residue, manures and fertilisers.

Distribution pattern of non-exchangeable potassium at different soil depth are presented in Table 5. The non-exchangeable potassium varied from 1124.21-1256.36, 1227.42-1290.67, 1255.99-1367.77, 1436.80-1518.39 kg ha^{-1} respectively in (0-15 cm), (15-30 cm), (30-45 cm), (45-60 cm) soil depth. The application of the highest level of fertilizer (T1) RDF + K mineral @ 210 kg K_2O kg ha^{-1} recorded highest level of non-exchangeable K (1518.39) kg ha^{-1} in subsurface layer (45-60 cm) and the lowest value of non-exchangeable K recorded in control (1436.80) kg ha^{-1}. The data revealed that non-exchangeable K content increased with increasing depth. The application of RDF + K mineral @ 210 kg ha^{-1} recorded highest non-exchangeable K in all depths but was statistically at par with rest of the treatment. The results of present study could be assigned to the fact that non-exchangeable potassium is typically held at inter-lattice positions and this form is not exchangeable by NH_4OAC (Ramamoorthy and Velayutham 1976) [10], and release of fixed K to compensate the removal of water-soluble K and exchangeable K by plants. The variation in the depth-wise distribution pattern of non-exchangeable K could be attributed to changes in particle size distribution in different layers (Brar and Sekhon 1987) [2].

Total potassium content in soil ranged from 0.8-0.83, 0.9-0.94, 0.01-1.02, 1.04-1.11% in (0-15 cm), (15-30 cm), (30-45 cm), (45-60 cm) soil depth is presented in Table 6. The highest content of total K was recorded with the application of RDF + K mineral @ 210 kg ha-^{1} at (45-60 cm) soil depth and lowest in control. The total K content among different rate of K mineral application along with RDF was statistically at par in each soil depth. Total K was higher in subsurface layer (45-60 cm) than at surface layer. This might be due to the fact that clay mineralogy is a key factor affecting the dynamics of K in soils (Ghiri and Abtahi 2011) [4], and also to the fact that total potassium in soil occurs as a structural component of soil minerals and is therefore inaccessible to plants. Total potassium content depends on type of soil fraction, primary and secondary material, and parent material (Dhakad *et al.* 2017) [3].

Correlation of different potassium fractions

The results of correlation study among different potassium fractions are presented from Table 7 to Table 10 which revealed that water soluble K was significantly and positively correlated with exchangeable K (r=0.456) and non-exchangeable K (r=0.508). Positive and significant relationship with water soluble K, exchangeable and non-exchangeable K indicated the existence of dynamic equilibrium between these forms of K. Exchangeable K was significantly and positively correlated with non-exchangeable K (r=0.529) and positively correlated with other forms of potassium and indicated the existence of dynamic equilibrium between these forms of potassium. Exchangeable K is also positively correlated with different forms of K. Intense weathering of primary and secondary K-minerals such as micas, feldspar and micaceous minerals of the clay fractions seems to maintain dynamic equilibrium among various forms of K.

Conclusion

The result of depth wise distribution of potassium fractions revealed that available K, water soluble K and exchangeable K were higher in surface layer and was found lower in subsurface layer and also decreased with increased in depth whereas non-exchangeable and total K was higher in subsurface layer and lower in surface layer and increased with increased in depth. The application of K mineral along with RDF influenced the content of water soluble K and available K at 0-15 cm and 15-30 cm and 0-15 cm soil depth respectively. However exchangeable K and non-exchangeable K and total K were not affected by application of K mineral irrespective of soil depth. The different fractions of potassium available K, water soluble K exchangeable K and non-exchangeable potassium are positively and significantly correlated with each other. These relationships indicate that there was a dynamic equilibrium between these forms of K, and that depletion of one is immediately replenished by one or more of the other forms of potassium.

Table 2: Depth wise distribution of water soluble K

S. No.	Treatment	0-15cm	15-30cm	30-45cm	45-60cm
T1	RDF + K mineral @ 210 kg ha^{-1}	20.89	19.19	16.81	13.42
T2	RDF + K mineral @ 150 kg ha^{-1}	20.09	18.77	16.42	12.25
T3	RDF + K mineral @ 120 kg ha^{-1}	19.82	18.60	15.50	11.75
T4	RDF + K mineral @ 140 kg ha^{-1}	20.41	19.27	15.96	12.64
T5	RDF + K mineral @ 110 kg ha^{-1}	19.65	17.69	15.59	12.10
T6	RDF + K mineral @ 70 kg ha^{-1}	19.74	19.27	15.89	13.01
T7	100% RDF Basal 100:60:40	19.33	18.86	15.88	11.53
T8	100% NP, K0	16.01	17.12	15.23	11.38
	SEM±	0.58	0.51	0.55	0.67
	CV	5.03	4.73	5.95	9.33
	CD	1.71	1.5	NS	NS

Table 3: Depth wise distribution of Available K

S. No.	Treatment	0-15cm	15-30cm	30-45cm	45-60cm
T1	RDF + K mineral @ 210 kg ha^{-1}	287.78	283.97	276.52	267.80
T2	RDF + K mineral @ 150 kg ha^{-1}	285.19	280.41	273.98	266.77
T3	RDF + K mineral @ 120 kg ha^{-1}	284.07	277.33	272.23	264.62
T4	RDF + K mineral @ 140 kg ha^{-1}	284.60	278.64	269.95	261.74
T5	RDF + K mineral @ 110 kg ha^{-1}	284.20	279.36	271.63	266.37
T6	RDF + K mineral @ 70 kg ha^{-1}	282.17	275.08	266.29	261.42
T7	100% RDF Basal 100:60:40	282.02	275.65	267.77	261.12
T8	100% N P, K0	268.99	273.67	265.90	262.24
	SEM±	3.66	3.13	2.73	2.78
	CV	2.23	1.94	1.74	1.82
	CD	10.71	NS	NS	NS

Table 4: Depth wise distribution of Exchangeable K

S. No.	Treatment	0-15cm	15-30cm	30-45cm	45-60cm
T1	RDF + K mineral @ 210 kg ha^{-1}	883.8	819.18	787.19	667.17
T2	RDF + K mineral @ 150 kg ha^{-1}	862.5	812.46	777.90	659.81
T3	RDF + K mineral @ 120 kg ha^{-1}	858.2	811.02	767.71	656.38
T4	RDF + K mineral @ 140 kg ha^{-1}	879.7	815.31	775.67	658.44
T5	RDF + K mineral @ 110 kg ha^{-1}	855.3	813.67	773.43	656.89
T6	RDF + K mineral @ 70 kg ha^{-1}	869.5	807.66	772.85	652.32
T7	100% RDF Basal 100:60:40	855.3	797.26	765.87	652.23
T8	100% NP, K0	838.4	791.83	759.63	649.17
	CD	NS	NS	NS	NS

Table 5: Depth wise distribution of non-exchangeable K

S. No.	Treatment	0-15 cm	15-30 cm	30-45 cm	45-60 cm
T1	RDF + K mineral @ 210 kg ha^{-1}	1256.36	1290.67	1367.77	1518.39
T2	RDF + K mineral @ 150 kg ha^{-1}	1234.93	1278.53	1336.62	1494.33
T3	RDF + K mineral @ 120 kg ha^{-1}	1212.49	1241.86	1306.77	1489.57
T4	RDF + K mineral @ 140 kg ha^{-1}	1206.06	1252.99	1353.68	1502.06
T5	RDF + K mineral @ 110 kg ha^{-1}	1208.41	1264.45	1322.46	1466.84
T6	RDF + K mineral @ 70 kg ha^{-1}	1203.17	1258.84	1365.97	1469.70
T7	100% RDF Basal 100:60:40	1197.47	1240.36	1323.11	1447.85
T8	100% NP, K0	1124.21	1227.42	1255.99	1436.80
	CD	NS	NS	NS	NS

Table 6: Depth wise distribution of total K

S. No.	Treatment	0-15cm	15-30cm	30-45cm	45-60cm
T1	RDF + K mineral @ 210 kg ha^{-1}	0.83	0.94	1.02	1.11
T2	RDF + K mineral @ 150 kg ha^{-1}	0.81	0.95	0.98	1.09
T3	RDF + K mineral @ 120 kg ha^{-1}	0.81	0.89	0.99	1.08
T4	RDF + K mineral @ 140 kg ha^{-1}	0.81	0.93	1.03	1.07
T5	RDF + K mineral @ 110 kg ha^{-1}	0.8	0.94	0.98	1.11
T6	RDF + K mineral @ 70 kg ha^{-1}	0.8	0.93	1.02	1.05
T7	100% RDF Basal 100:60:40	0.8	0.92	0.96	1.09
T8	100% NP, K0	0.8	0.9	1.01	1.04
	CD	NS	NS	NS	NS

Table 7: Correlation of different potassium fractions at 0-15 cm depth.

	Available K	Water Soluble K	Exchangeable K	Non-exchangeable K
Available K	1			
Water Soluble K	0.612*	1		
Exchangeable K	0.459*	0.456*	1	
Non-exchangeable K	0.322	0.508*	0.037	1

Table 8: Correlation of different potassium fractions at 15-30 cm depth.

	Available K	Water Soluble K	Exchangeable K	Non exchangeable K
Available K	1			
Water Soluble K	0.284	1		
Exchangeable K	0.492*	0.378	1	
Non-exchangeable K	0.068	0.036	0.366	1

Table 9: Correlation of different potassium fractions at 30-45 cm depth.

	Available K	Water Soluble K	Exchangeable K	Non exchangeable K
Available K	1			
Water Soluble K	0.154	1		
Exchangeable K	0.469*	0.301	1	
Non exchangeable K	0.104	0.222	0.529*	1

Table 10: Correlation of different potassium fractions at 45-60 cm depth.

	Available K	Water Soluble K	Exchangeable K	Non-exchangeable K
Available K	1			
Water Soluble K	0.092	1		
Exchangeable K	0.227	0.433*	1	
Non- exchangeable K	0.161	0.283	0.320	1

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