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Studies on potassium fraction as influenced by nutrients management practices under rice-wheat cropping system

Riya Upadhayay[1]*, Rakesh Banwasi[1], LK Srivastava[1], D Khalkho[2], Gaurav Jatav[1], Vivek Patel[1]
[1] Department of Soil Science and Agricultural Chemistry, College of Agriculture, Raipur Indira Gandhi Agricultural University, Raipur, Chhattisgarh, India
[2] Department of Soil and Water Engineering, Swami Vivekanand College of Agricultural Engineering Technology and Research Station, Indira Gandhi Agricultural University, Raipur, Chhattisgarh, India

Abstract
A field experiment was carried out at Instructional Farm of Indira Gandhi Agricultural University Raipur (C.G.), during the Kharif season of 2019. The study entitled "Studies on potassium fraction as influenced by nutrients management practices under rice-wheat cropping system" was carried out under the long term fertilizer experiment in the *Vertisol*. The objectives of the study were - to study the distribution of various fractions of potassium in *Vertisol*, potassium balance in the soil and correlation between yield and K fractions.The experiment was consisting of five treatments and four replications in a randomised block design (RBD). The treatments were T1 (control with 0:0:0 kg/ha N: P_2O_5: K_2O), T2 (general recommended dose for rice 100:60:40) T3 (STCR based inorganic fertilizer to achieve target yield 5 t ha^{-1}), T4 (STCR based inorganic fertilizer to achieve target yield 6 t ha^{-1}), and T5 (STCR based inorganic fertilizer with 5 t ha^{-1} FYM to achieve target yield 6 t ha^{-1}). Fertilizer prescription equations used for the calculation of fertilizer for a definite targeted yield of rice variety MTU-1010 in *Vertisol* were developed by AICRP on STCR, IGKV, Raipur as FN= 4.05T- 0.57SN- 0.78ON, FP= 1.46T- 3.09SP- 0.31OP and FK= 1.61T - 0.10SK- 0.14OK. Among all the treatments, significantly higher water soluble K content (23.2 kg ha^{-1}) was found in the treatment- T5 while lowest water soluble K were found with the control (8.79 kg ha^{-1}). Exchangeable fraction of potassium were also observed highest (676.2 $kgha^{-1}$) with the treatment -T5 which was found at par with treatment -T4 and observed significantly superior over other treatments (T1, T2, T3). Lowest exchangeable-K (610.1 $kgha^{-1}$) was found in the control treatment. Improvement in water soluble and exchangeable-K fractions in the soil were may be due to the continuous application of balanced fertilization (with or without FYM). Highest value of non-exchangeable-K (2324 $kgha^{-1}$) was observed in the treatment -T4 and found at par with the treatment -T5 (2311 $kgha^{-1}$) and treatment -T2 (GRD). These treatments (T2, T4 and T5) were found significantly higher over the treatment- T3. Lower non-exchangeable potassium in the treatment- T3 was may be due to the long term application of lower doses of potassium. Significantly lowest non exchangeable –K was observed with control (1848 $kgha^{-1}$). Overall finding shows that the highest values of all fractions of potassium were recorded in the treatment-T5 and lowest was found in the control. Apparent K balance influenced nutrients management practices under rice-wheat cropping system in *Vertisol* revealed that, the highest negative balance (-115.9 kg/ha) were recorded in organic treatment T5 followed by treatment T4 and T2 and lowest (-32.6 kg/ha) were found in treatment control. This is due to the fact that K application seldom matches K removal, resulting in greater dependence on soil K. Among different K fractions non-exchangeable potassium was observed as the most important potassium fraction contributing towards grain yield by rice. It contributes 95% variation in grain yield.

Keywords: integrated nutrient management, long-term, organics, potassium fractions, potassium balance

Introduction
Chhattisgarh state is popularly known as "Rice bowl of India" covering maximum area under rice during Kharif and contributes major share in national rice production. In Chhattisgarh, area under rice cultivation is 3.28 million hectare (7.75 % of cultivated area of India) and the production is 6.08 million tones (5.38 % of rice production of India). Rice-wheat cropping system is a common practice in the area where the irrigation facility is sufficient for second crop. The area under wheat is approximately 1.62 lakh ha with the production of 141 tonnes and productivity of 1155 kg ha^{-1} **(**Agristatglance, 2018**)** [1]**.** The production and productivity of both the crops are very low in the state.

Potassium, a major plant nutrient has long been a neglected nutrient in Indian Agriculture. Ironically, India depends entirely on imports for potassium fertilizers, which are very expensive. In most of the cropping systems practiced in India, the balance of potassium (K) is negative because the application of K seldom matches its removal. The current practice of applying potassium without taking into consideration of soil K status as well as plant demand is either limiting the crop yield or causing K mining.

In the Chhattisgarh, per hectare consumption of potash in Kharif has been increased from 6 kg in 2012 to 7 kg in 2018 with highest consumption of 11 kg in 2016 (Agriculture Development and Farmer Welfare and Bio-Technology Department)

Fractionation of a nutrient is generally done to know the number of particular nutrients associated with different soil fractions or to know the number of various forms of elements present in the soil. Potassium constitute an average of 2.6% of the earth's crust, making it the fourth most abundant mineral nutrient and the seventh most abundant element in the lithosphere (Schroeder, 1978) [18].

There are four different sources of potassium in the soil. The soil minerals such as mica and feldspar are the major source of K constitutes 90 to 98% of total K, but its availability for plant use in very less amount. The second potassium source is the non-exchangeable potassium which is associated with the 2: 1 clay mineral and constitutes 1 to 10% of potassium in the soil. The third potassium source is the exchangeable or readily available potassium which constitutes about 1 to 2 % of total K, which is readily taken up by the plants and is found on the cation exchange sites or in the soil solution (Rehm & Schmitt, 2002) [14]. A fourth potassium source is the potassium contained in organic matter and within the soil microbial population. These provide very little of the potassium needed for plant growth.

"Only 1 to 2 percent of total K is readily available to plant and exists in soil in two forms, *viz*., solution K adsorbed on soil colloidal surface and exchangeable (Brady and Weil, 2002) [4]. These forms remain in dynamic equilibrium with each other. In the initial stage the readily available or water-soluble K has been reported to be a dominant fraction while non-exchangeable and exchangeable K contributes more in the later stages of crop growth (Subehia et *al.* 2003) [20]. Therefore, the study of the potassium fraction in the soil under a long term practice of soil test based fertilizer application along with organic manure for achieving a definite yield of rice under a balanced nutrients use to be of great importance for improvement of soil potassium fertility.

Materials and Methods

The field experiment was conducted at Instructional Farm of College of Agriculture, Indira Gandhi Agricultural University, Raipur, Chhattisgarh. Field experiment was started in Kharif, 2019 and continued to Rabi 2020 on the Vertisol. Geographically, Raipur is situated in the center of Chhattisgarh and lies between 21^0 16'N latitude and 81^0 60'E longitude with altitude of 289.56 meters the mean sea level. The research farm is situtated on NH 6 in the eastern part of Raipur city and located between 20^0 4' North latitude and 81^0 39' East longitude with altitude of 293 m above mean sea level.

The soil of the experimental field was deep black and clayey in texture (*Vertisols*). Physico- chemical properties of experimental soil during the 13 th cycle of the cropping system was analysed and average values were used as initial. Soil reaction of initial soil was slightly alkaline (pH 7.84) with 0.18 dSm^{-1} EC, and organic carbon content was medium (0.53%). Soil was low in available nitrogen (215.8 kg ha^{-1}), medium in available phosphorus (18.9 $kgha^{-1}$) and high in available potassium (496.9 $kgha^{-1}$).

Soil samples were collected from 0-0.15 m depths after the harvest of rice (*Kharif*, 2019).

Scheme of Potassium fractionation

Four major fractions of potassium *viz*., water-soluble, available, exchangeable and non-exchangeable were analyzed by using the following methods.

A. Water-soluble K: Water soluble potassium was estimated in 1:5 soil water suspensions after shaking it for one hour and then potassium was estimated in the filtrate by flame photometer (Black, 1965) [3].

B. Available potassium: Available potassium was extracted from soil by shaking 5 grams of soil with 25 ml neutral normal ammonium acetate (Hanway and Heidel, 1952) [5] and was determined by using Flame photometer as described by Jackson (1967) and expressed as kg K_2O ha^{-1}.

C. Exchangeable K: This was determined by centrifugation and decantation procedure as described by Black (1965) [3].Ten gram of soil sample was placed in 50 mL centrifuge tube and 25 mL ammonium acetate was added. Thereafter, the content was centrifuged for 10 minutes. The supernatant was decanted into 100 mL volumetric flask. Three additional extractions were made in the same manner. These combined extracts were diluted to 100 mL with ammonium acetate, the solution was mixed thoroughly and potassium was determined by flame photometer.

D. Non-exchangeable K: Two gram of soil was placed in digestion tube and 20 mL of 1 N HNO_3 was added. The content was boiled for 10 minutes and suspensions were then filtrated through Whatman filter paper No. 1 and potassium was estimated in the filtrate by flame photometer (Wood and De Turk 1941) [21].

Results and Discussion

Potassium Fractions

Water soluble potassium

The data of water soluble potassium (kg/ha) in the soil at harvest (Table-1) shows that water soluble potassium was significantly influenced by various inorganic and organic treatments. Water soluble K content of the soil varied from a minimum of 8.79 kg/ha in the control (T1) to maximum of 23.19 kg/ha in the treatment where 5 t ha^{-1} FYM were incorporated along with the STCR based inorganic fertilizer to achieve the target yield of 6 t ha^{-1} (T5). Treatment T5 significantly improved the water soluble K content in the soil as compared to other treatments. Water soluble potassium content in the treatment T5 was found 29 and 49.7 percent higher than the T3 (YT 5 t ha^{-1}) and T4 (YT 6 t ha^{-1}), respectively. Higher content of water soluble potassium may be attributed to its additions through potassic fertilizers, organic manures, weathering, and release of labile potassium from organic residues and upward movement of potassium from lower depth with capillary water rise (Ranganathan and Satyanarayana, 1980) [13]. Significantly increase in water soluble potassium due to inorganic fertilizers alone or in combination with FYM over control were also found by Jadhao *et al.* (2018) [7] and Kurbah (2017) [8]. Increase in water-soluble K due to favorable influence of organics was also reported by Santhy *et al*. (1998) [16].

Exchangeable potassium

The data of exchangeable K fractions under different treatments in the soils at harvest of rice (Table 1) shows that among the various treatments highest exchangeable- K (676.2 kg/ha) was recorded in treatment T5 (where FYM @ 5 ha^{-1} were incorporated along with the inorganic fertilizers to achieve the target yield of 6 t ha^{-1}) followed by treatment T4 with 671.9 kg/ha (inorganic fertilizers for YT 6 t ha^{-1}). Both the treatments were found at par. Significantly lowest value of exchangeable K (610 kg/ha) was found under control treatment (T1). The highest exchangeable potassium in the treatment- T5 was may be due to incorporation of FYM along with the inorganic fertilizer which can hold more

Exchangeable potassium and also due to the conversion of the exchangeable- form of potassium from non-exchangeable form of potassium as a consequent to mass action effect (Sawarkar *et al*., 2013, Meena and Biswas, 2014) [17, 10]. Improvement in exchangeable-K fractions in the soil due to continuous application of chemical fertilizers and incorporation of amendments (FYM) along with the inorganic fertilizers were also reported by Sood *et al.* (2008) [19] and Mazumdar *et al.* (2014) [9]

Non exchangeable potassium

The data of non-exchangeable- K fractions under different treatments in the soil at harvest of rice presented in the Table 1 indicated that non-exchangeable-K was significantly affected by the various nutrient management practices. Highest value of non-exchangeable-K 2324 kg/ha was observed in the treatment where inorganic fertilizer applied for 6 t ha^{-1} yield target of rice (T4) and found at par with the treatment -T5 (2311 kg/ha) where FYM @ 5 t ha^{-1} incorporated along with the inorganic fertilizer to achieve target yield 6 t ha^{-1} and treatment -T2 (GRD). These treatments (T2, T4 and T5) were found significantly higher over the treatment T3 (YT 5 t ha^{-1}). Significantly lower non-exchangeable potassium in the treatment T3 as compared to T2, T4 and T5 was observed due to the long term application of lower doses of potassium (30 kg ha^{-1} in the rice) in the T3 whereas the treatments T2, T4 and T5 were received potassium more than 40 $kgha^{-1}$ in the rice crop. Application of NPK alone T4 (YT 6 t ha^{-1}), T3 (YT 5 t ha^{-1}) and T2 (GRD) or in combination with organics i.e. T5 (YT 6 t ha^{-1} with FYM), resulted significantly higher content of non-exchangeable potassium as compared to T1 (control). Similar result was also reported by Pannu *et al.* (2001) [11].

In a long-term fertilizer experiment, decline in non-exchangeable-K in the control plots (no potassic fertilizer) was also observed by Singh *et al.* (2014). When crops are grown successively without potassium application, the demand for the nutrient increases and the soil available pool remains constantly under potassium stress. Hence the flow of potassium in the dynamic equilibrium system is from non-exchangeable form thus leading to a considerable decline of the former (Sachdev and Khera, 1980) [15].

Distribution of potassium fractions

Among all the fractions, water soluble potassium was observed the least dominant fraction (Table 1). Among the different fractions contributing to the total inorganic potassium (excluding the minerals K), the contribution of non-exchangeable potassium was highest compared to other fractions.

The value of potassium fractions (kg/ha) were found in the order of non-exchangeable, exchangeable, available and water soluble potassium. Similar results were also reported by Pascricha (2002), Bachkaiya (2005) [2] and Jadhao *et al.* (2018) [7].

Table 1: Effect of Nutrients Management Practices on Different Farm and Fractions of Potassium (kg/ha) in the Soil after Harvesting of Rice.

Treatments details**		Form of potassium	Fractions of potassium (kg/ha)			
		Available-K (kg/ha)	Water soluble-K	Exchangeable-K	Non exchangeable-K	Total inorganic-K (excluding the minerals K)
T1	Control	422.87	8.79 (0.36)	610.10 (24.72)	1848.73 (74.92)	2467.62
T2	GRD	487.18	12.57 (0.42)	647.34 (21.89)	2297.75 (77.69)	2957.66
T3	YT 5 t ha^{-1}	502.17	15.49 (0.54)	660.02 (23.15)	2175.60 (76.31)	2851.11
T4	YT 6 t ha^{-1}	520.26	17.97 (0.60)	671.89 (22.29)	2324.98 (77.12)	3014.84
T5	YT 6 t ha^{-1} with FYM	550.80	23.19 (0.77)	676.25 (22.46)	2311.00 (76.77)	3010.44
	SEm+	9.87	0.44	2.13	9.54	-
	CD	30.42	1.36	6.56	29.38	-
	CV	3.98	5.65	0.65	0.87	-

Conclusion

The distribution of various fractions of potassium"(water soluble, exchangeable, non-exchangeable and available K) in the surface (0-15 cm depth) of *Vertisols* under a long term fertilizer experiment were studied. Water soluble and exchangeable fractions of potassium were found higher in the treatment where 5 t ha-1 FYM were incorporated along with the inorganic fertilizers to achieve target yield 6 t ha^{-1} (T5) followed by the treatments where inorganic fertilizer applied to achieve target yield 6 t ha^{-1} (T4), inorganic fertilizer applied to achieve target yield 5 t ha^{-1} (T3), treatment where general recommended dose were applied (T2) and were lowest in the treatment where no fertilizers were applied (T1). In case of non-exchangeable K fraction, decline in non-exchangeable -K in the control plots was observed. Significantly lowest non-exchangeable K (1849 kgha-1) was recorded in control plot (T1) due to the continuous removal of k from the soil without any addition of potassic fertilizer. Highest amount non-exchangeable K was seen in the treatment (T4) where inorganic fertilizer applied to achieve target yield 6 t ha^{-1}. Significantly lower non-exchangeable potassium in the treatment T3 (2176 kg ha^{-1}) as compared to T2 (2298 kg ha^{-1}), T4 (2325 kg ha^{-1}) and T5 (2311 kg ha^{-1}) were observed due to long term application of the lower dose of potassium (30 kg ha^{-1} in the rice) in the T3 whereas the treatments T2, T4 and T5 were received more than 40 kg ha^{-1} potassium in the rice crop.

"The sequential order of dominance of different forms K were non-exchangeable > exchangeable > available > water soluble were observed.

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