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Effect of Long-term Continuous STCR based Fertilization on Potassium Pools and Balance in Calcareous Soil under Rice based Cropping System

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Potassium (K) is essential for soil, plant and human nutrition. In calcareous soils, high Ca levels suppress the K uptake by the crops therefore, crops growing in these soils often require above normal levels of K fertilization for satisfactory plant growth. Therefore, a long-term experiment was started in calcareous soil (medium in available K) replicated thrice in randomized block design with rice-based cropping system and nine treatments [T_1- control, T_2-FP, T_3-GRD, T_4-YT 35q/ha, T_5-YT 40 q/ha, T_6-YT 45 q/ha, T_7-STCR (YT 35 q/ha) + IPNS, T_8-STCR (YT 40q/ha) + IPNS, T_9-STCR (YT 45 q/ha) +IPNS at Experimental Farm, RPCAU, Pusa, Samastipur, Bihar, India during kharif-2019. Continuous addition of STCR based fertilizer along with 5 tons ha^{-1} compost improved soil organic carbon, CEC, available potassium status and potassium balance whereas control unfertilized decreased the most, results unsustainable yields and soil fertility. Treatment T_9 for rice

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based cropping system was superior over all the other treatments in potassium fractions, chemical properties and potassium balance of surface (0-15 cm) and sub-surface soil (15-30 cm).

Keywords: Potassium; fractions; balance; fertilization; pools; calcareous; soil test crop response.

1. INTRODUCTION

Globally, Rice (*Oryza sativa* L.) is the principle food crops with respect to area and production and provided as food for more than 50 percent world population [1]. Rice-wheat (*Triticum aestivum* L.) cropping system is predominant in South Asia [2], which mainly include countries like India, Bangladesh and Pakisthan. Both are the staple food grain crops of Indo-Gangetic plain and the area occupies about 13.5 million ha of the region including 10 million ha in India [3]. The maize (*Zea mays* L.) production increasing in south Asia as a human food and animal nutrition. Increasing productivity of maize while decreasing production costs and maintaining soil health emerging challenge for the rice-maize system in South Asia. In India, maize is grown on 9.4 m ha, with annual production of about 27.78 million tons and production of mustard (*Brassica spp.*) 11.75 million tons with productivity 1458 kg ha^{-1} and area harvested 8.06 m ha [4].

The vital roles of K are like enzyme activation, energy relations, osmotic regulation, assimilates translocation, starch and protein synthesis and helping in sustainable productivity [5-7]. The dynamic interaction of K maintains the availability of K [8]. Severe loss of potassium partly results from the average crop removal of 1.5 times more K than that of N, while the K application is much lower than that of N or P, with the misconception that the soils of country are relatively rich in potash [6]. Ignorance of balance nutrition with potash is decline crop yield and reducing the available pool of potassium from the soil (Mani Mesha 2019). Potassium present in different primary minerals followed the order: muscovite > feldspar > biotite. A major portion of potassium exists in finer fraction of soil [9]. Cropping and nutrition are the most important managing factors that influence K dynamics in soil [10]. The Soil test based fertilizer recommendation harmonizes the much debated approaches namely, “Fertilizing the soil” versus “Fertilizing the crop” ensuring for true balance (not apparent balance) between the applied fertilizer nutrients among themselves and with the soil available nutrients. Based on this concept, soil test crop response studies have been undertaken in different parts of India in various crops like wheat, rice, pearl millet [11]. The use of fertilizer containing no K may also affect the K status in soil. Worldwide availability and good feedback by the crops further stressed K variation [12]. WSK has been reported to be a dominant form in the initial stage while exchangeable and non-exchangeable K essential in the later stages of plant life [13].

Rice-wheat cropping system is the most important cropping system in Indo-Gangetic plain of India. It is being realized that when crops are grown in sequence, the fertilizer requirements of the cropping system as a whole is important than that of individual crop. The targeted yield concept is based on soil test crop response correlated with soil fertility status and nutrient requirement of the crop [14]. The long-term effect on soil properties and potassium fractions as influenced by nutrient management with compost and chemical fertilizer applied alone or in combination using STCR-based targeted yield equations under a seven-year old rice based cropping system. The main objectives of this research to know about the potassium status and balance after long-term fertilization of potassic fertilizers.

2. MATERIALS AND METHODS

2.1 Location of the Field Experiment

A field experiment was conducted during *Kharif*-2019 under a long-term fertility experiment of Soil Test Crop Response (STCR) initiated in *Rabi*-2012 at experimental farm of Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India which was located at 25^0 94’N latitude, 85^0 67’ E longitude and an altitude of 52.3 meter above mean sea level. Sub-tropical climate conditions prevail in the experimental area with hot and humid summer and cold winter and an annual rainfall of about 1300 mm mostly during June to mid-October. During the study period, the monthly mean maximum temperature varied between 29.3 to 37.5^0C, with an average of 33.4^0C. The mean minimum temperature ranged between 22.1^0C to 26.8^0C, with an average of 25.3^0C.

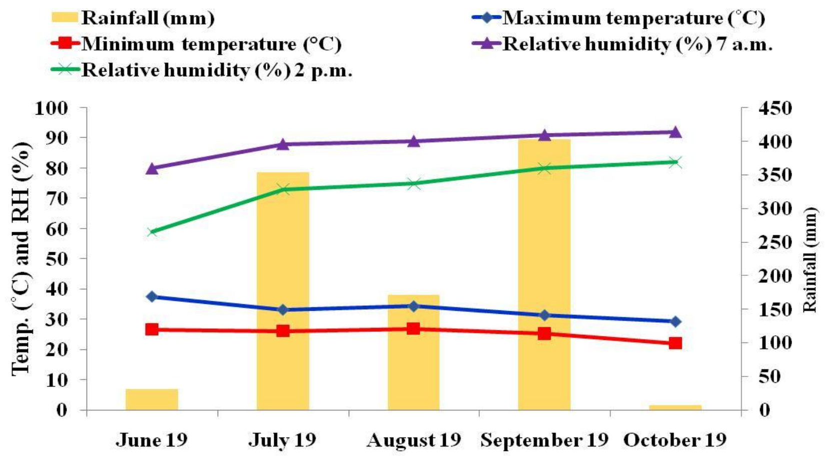


Fig. 1. Mean monthly precipitation, temperature and humidity during cropping season (Kharif-2019)

Table 1. Application of potassium fertilizer on the basis of STCR

Treatment	**K- fertilizer (Kg K_2O/ha)**		
	Rice (Rice-wheat cropping system)	**Rice (Rice-mustard cropping system)**	**Rice (Rice-maize cropping system)**
T_1: Control	0	0	0
T_2: Farmers practice	33	33	33
T_3: General Recommend Dose	40	40	40
T_4: STCR (YT35 q/ha)	37.4	50.0	23.8
T_5: STCR (YT40 q/ha)	47.2	58.9	28.5
T_6: STCR(YT45 q/ha)	55.8	67.6	36.1
T_7: STCR (YT35q/ha)+IPNS	28.3	45.2	11.0
T_8: STCR (YT40q/ha)+IPNS	36.7	53.6	17.1
T_9: STCR (YT45q/ha)+IPNS	44.8	62.0	24.2

Where as; GRD= General Recommended Dose; YT = Yield Target; IPNS = Integrated Plant Nutrient System (in IPNS, 5 tonnes compost ha^{-1} was supplied); STCR= Soil Test Crop Response

Overall, the highest temperature showing month was June. It receives a mean rainfall of 193.1 mm and it was maximum during the month of September-2019. The fertilizer K dose for rice crop was calculated as per STCR equation and accordingly applied during kharif-2019 is depicted in Table 1.

2.2 Experimental Details and Treatments

The ongoing research experiment started in 2012 at experimental farm, Department of Soil Science, in which treatments were applied under Randomized block design and replicated thrice in plots measuring 2.5 x 4 m^2 dimensions for rice based cropping system by growing Rajendra Bhagwati (rice) and Prabhat (rice) during *Kharif*-2019 and supply of irrigation through check basin method. The treatments selected for this study consisted *viz*. T_1-Unfertilized (control), T_2-Farmers practice, T_3- General recommend dose, T_4- STCR-based fertilizer for yield target 35 q ha^{-1}, T_5 - STCR-based fertilizer for yield target 40 q ha^{-1}, T_6- STCR-based fertilizer for yield target 45 q ha^{-1}, T_7- STCR-based fertilizer with 5 tons ha^{-1} compost for yield target 35 q ha^{-1}, T_8- STCR-based fertilizer with 5 tons ha^{-1} compost for yield target 40 q ha^{-1}, T_9- STCR-based fertilizer with 5 tons ha^{-1} compost for yield target 45 q ha^{-1}. Recommended dose of fertilizers was given through Urea, Di-Ammonium Phosphate, Murate of potash and Compost 5 tons ha^{-1}. The following STCR based equations were used for calculation of fertilizer doses:

Rice-wheat	Rice-mustard	Rice-maize
F K_2O = 1.73T – 0.24 S K_2O - 0.24 C K_2O	F K_2O = 1.75T – 0.20 S K_2O - 0.15 C K_2O	F K_2O =1.56 T – 0.41 S K_2O - 0.13 C K_2O
Where, F K_2O, T, S K_2O and C K_2O stand for Fertilizer rate of K_2O, treatment, soil and crop; respectively		

2.3 Soil Sampling and Analysis

To estimate the various soil parameters, soil samples were taken from field at two depths (0-15 cm and 15-30 cm) after harvest the crop. The soil samples were air-dried and passed through a 2 mm sieve for laboratory experiments. Soil pH and electrical conductivity were measured in a 1:2 soil to water ratio [15]. Organic carbon (OC) was determined by dichromate oxidation [16]. Different parameters, *viz.*, CEC [17], potassium fractions and potassium balance were estimated by standard procedure [15].

2.4 Statistical Analysis

The research data were analyzed with the help of analysis of variance with OPSTAT [18]. OPSTAT is a free online agricultural data analysis tool developed by O.P. Sheoran, Computer Programmer at CCS HAU, Hisar, India (http://14.139.232.166/opstat/). The mean values of treatment were separated by Fischer's protected least significant difference (LSD) test at $P \leq 0.05$.

3. RESULTS AND DISCUSSION

3.1 Soil Properties

The soil sample collected from surface (0-15 cm) and sub-surface (15-30 cm) soil with help of auger. These soil alkaline in pH (1:2, soil: water) ranged between 8.03-8.34 and 8.19-8.35 in surface and sub-surface soil, normal in salinity, medium in organic carbon varied from 0.33-0.53, 0.24-0.44, and 0.34-0.51 percent in rice-wheat, rice-mustard and rice-maize cropping system; respectively. The CEC of soil between 6.6 to 11.3 (Cmol (p+) kg^{-1}) in rice-based cropping system (Table 2). Long-term application of organics and also addition of more root biomass under STCR along with compost treated plots released organic acids and carbon dioxide (CO_2) into the soil during the decomposition and caused decline in pH [14,19]. Integration of organics with inorganics showed the significant improvement of organic carbon content in post-harvest soil [20].

3.2 Pools of Potassium

Seven years of continuous fertilization, cropping and manuring in the form of STCR based fertilization along with compost to rice crop resulted in enrichment of different fractions of K in soil. The maximum content of WSK and AAK in surface soil was found under T_9 treatment and varied in the ranges 5.5-7.8, 5.5-7.3 and 5.8-8.1 mg kg^{-1} under rice-wheat, rice-mustard and rice-maize cropping system (Table 3); respectively. In sub-surface soil the content of WSK and AAK highest in T_9 treatment with value 7.7 mg kg^{-1} rice-wheat and followed by 38.2 mg kg^{-1} in rice-maize cropping system (Table 3). The plots receiving STCR based fertilizer along with IPNS increased the concentration of WSK and AAK. The application of FYM (at 25 t ha^{-1}) and 50%NPK + 10 t FYM ha^{-1}, the status of potassium fractions was found to be increased. They also highlighted that for sustain K nutrition of soil for long time, it is important to add organic nutrient sources with inorganic ones for retained available soil potassium status in soil [21,9].

The highest content HNO_3 and NEK were quantified in T_8 treatment varied from 532.8-625.9 and 506.3-586.6 mg kg^{-1} in rice-wheat cropping system and lowest content reported in T_1 treatment (control) followed by Farmer practices and GRD (Table 3). The HNO_3 K was found statically non-significant in sub surface soil. Surface soil K reserve is highly susceptible to exhaustion than sub-surface soil K reserve. Around 90 per cent of K_{nitric} consists of K edges to soil solid particles with much considerable strength than exchangeable K [22]. The non-exchangeable K portion was lower in sub-surface soil than surface soil might be due to fertilizer application to the surface soil that has maintained much of applied K [23]. The high portion of NEK in STCR (YT45q/ha)+IPNS might be due to continuous application of compost maintained higher level of NEK over control unfertilized (T_1) whereas constant depletion of K in the fertilizer schedule non-exchangeable-K [24-26].

Table 2. Effect of different treatments on cation exchange capacity of surface and sub-surface soil under rice based cropping system

Treatments	Rice-wheat		Rice-mustard		Rice-maize	
	CEC cmol(p+) kg^{-1}		CEC cmol(p+) kg^{-1}		CEC cmol(p+) kg^{-1}	
	0-15cm	15-30 cm	0-15cm	15-30 cm	0-15cm	15-30 cm
T_1	7.4	5.2	6.6	4.8	6.8	4.8
T_2	8.4	5.2	7.7	5.6	6.9	5.1
T_3	8.5	5.2	7.6	5.9	7.5	5.1
T_4	8.9	5.2	8.3	5.9	7.9	5.4
T_5	9.0	5.9	8.7	6.3	8.7	5.6
T_6	9.2	6.2	8.2	6.3	9.2	6.1
T_7	9.6	6.3	8.9	6.7	9.5	6.3
T_8	10.2	6.6	9.3	6.7	9.8	6.8
T_9	10.6	6.8	9.9	6.7	10.2	6.9
SEm$\pm$	0.3	0.4	0.3	0.4	0.3	0.5
CD(p=0.05)	1.0	NS	0.9	NS	0.8	NS

Two fractions of K were quantified from different treatments: HCl K (Table 3) and H_2SO_4 K (Table 5). Each fractioned was highest under the T_9 treatment of Rice-wheat cropping system. The mineral fraction of K: biotite, mica and muscovite found statically significant in surface soil. The largest amount of mica K was found under the T_9 treatment, with value 9748.9 mg kg^{-1} in rice-wheat cropping system. The vital importance for addition higher dose of potassium in calcareous soil for maintaining soil K dynamics and sustain the soil productivity [27]. The biotite K content varied in the ranges 702.5-915.6, 846.7-989.9 and 893.9-1091.3 mg kg^{-1} in rice-wheat, rice-mustard and rice-maize cropping system (Table 6); respectively. Among all highest biotite K content in rice-maize followed by rice-mustard and rice-wheat cropping system. The muscovite potassium of studied soil was ranged varied from 6708.7- 8876.7, 6291.3- 7428.7 and 4910.7-5785.3 mg kg^{-1} in rice-wheat, rice-mustard and rice-maize cropping system; respectively (Table 6). The content of feldspar and total K in surface and subsurface soil were statically non-significant for rice based cropping system. The major amount of feldspars K in surface soil over sub-surface soil [9].

In case of subsurface soil the concentration of various fractions of potassium; AAK, HNO_3 K, NEK, HClK, and H_2SO_4 were statically non-significant for K concentration under rice based cropping system. The percentage contributions of the said fractions muscovite, feldspar and biotite to the total mineral K content in soil were 60 %, 33% and 7% in rice-wheat, 48%, 46% and 6% in rice-mustard and 59%, 34% and 7% in rice-maize cropping system, respectively (Fig. 2) in same order. The application of farm yard manure maintained or increased potassium status under long-term fertilizer experiment. The low available K in control unfertilized plot (T_1) in upper layer (0-15 cm) and lower layer (15-30 cm) might be due to intensive cropping without adding any source of potassium and high K uptake by plant [28-30].

3.3 Correlation between soil Properties and Different Fractions of Potassium

Correlation study (Table 6) of different form of K with soil properties showed that WSK was highly significant with CEC (r= 0.885**, r= 0.903** and r= 0.947) and organic carbon (r= 0.885**, r= 0.876** and r= 0.936**) content of surface soil under rice-wheat, rice-mustard and rice-maize cropping system. The positive and significant correlation between various fractions of K with other fractions of potassium like AAK, NEK, HCl K and Total K.

3.4 Potassium Balance (kg ha^{-1})

Apparent potassium balance was calculated from input of K (i.e. application of potassic fertilizer during Kharif-2019 and available K in soil) and output of K (i.e. uptake of K by crop during Kharif-2019 and change in available K in post-harvest soil after kharif-2019). The addition of K through irrigation and rainfall was not taken in to account. The lower potassium depletion recorded in rice-mustard followed by rice-wheat and rice-maize cropping system in T_9 treatment over T_1 (Fig. 3).

Table 3. Effect of different treatments on potassium fractions of surface soil (0-15cm) under rice based cropping system

Treatments	Rice-wheat					Rice-mustard					Rice-maize				
	WSK	**AAK**	**HNO_3K**	**NEK**	**HClK**	**WSK**	**AAK**	**HNO_3K**	**NEK**	**HClK**	**WSK**	**AAK**	**HNO_3K**	**NEK**	**HClK**
T_1	5.5	26.5	532.8	506.3	1235.3	5.3	17.6	337.5	319.9	984.0	5.8	27.0	467.3	440.4	1124.7
T_2	6.2	31.6	548.8	517.2	1282.7	6.2	18.4	338.7	320.3	1036.0	5.9	28.5	456.4	427.9	1216.0
T_3	6.4	32.2	583.3	551.2	1418.0	6.3	18.9	344.0	325.1	1052.7	6.4	27.3	469.7	442.5	1286.7
T_4	7.1	35.9	603.1	567.2	1422.0	6.9	20.9	383.7	362.8	1066.0	7.1	28.0	473.9	445.9	1325.3
T_5	6.6	34.1	605.6	571.5	1467.3	6.6	20.7	395.7	375.1	1085.3	7.2	30.7	506.7	475.9	1312.0
T_6	7.8	34.2	616.0	581.8	1489.3	7.3	20.8	400.1	379.3	1087.3	7.9	31.0	534.9	504.0	1366.7
T_7	7.3	38.9	625.9	580.7	1478.0	7.5	21.6	392.1	370.6	1108.0	7.2	36.0	488.8	452.8	1344.0
T_8	7.2	39.3	624.4	586.6	1503.3	7.2	22.2	395.7	373.6	1235.3	7.8	37.6	552.1	514.5	1406.0
T_9	7.8	40.0	621.7	584.4	1537.3	7.7	22.8	423.3	400.6	1266.7	8.1	38.2	584.3	546.0	1422.7
SEm±	0.3	1.6	15.7	16.2	35.5	0.5	1.0	11.7	11.7	32.0	0.4	1.2	19.1	19.2	32.4
CD(p=0.05)	1.0	4.8	47.2	48.6	106.4	1.4	3.1	35.0	35.0	96.0	1.1	3.7	57.4	57.5	97.2

Table 4. Effect of different treatments on potassium fractions of sub-surface soil (15-30 cm) under rice based cropping system

Treatments	Rice-wheat					Rice-mustard					Rice-maize				
	WSK	**AAK**	**HNO_3K**	**NEK**	**HClK**	**WSK**	**AAK**	**HNO_3K**	**NEK**	**HClK**	**WSK**	**AAK**	**HNO_3K**	**NEK**	**HClK**
T_1	4.9	35.0	538.7	503.7	1368.0	4.8	17.6	335.3	313.0	1024.7	4.7	26.4	507.9	481.4	1302.7
T_2	5.8	31.4	558.3	526.8	1460.7	5.5	18.4	340.9	320.3	1055.3	5.7	31.4	519.1	487.7	1324.0
T_3	4.1	33.0	590.8	557.8	1420.7	6.0	18.9	348.7	329.2	1114.7	5.8	29.2	498.4	469.2	1396.7
T_4	6.3	35.4	608.1	572.8	1460.0	6.3	20.9	383.5	363.0	1188.0	7.2	30.6	519.9	489.2	1362.7
T_5	5.9	35.8	617.2	581.4	1532.0	6.1	20.7	404.1	384.2	1163.3	6.2	31.0	530.3	499.3	1372.0
T_6	6.8	30.7	622.9	592.3	1664.7	6.3	20.8	4013	382.1	1198.7	7.0	31.3	600.0	568.7	1416.0
T_7	6.7	31.9	626.8	595.0	1622.7	6.7	21.6	404.3	384.0	1224.0	7.0	31.8	472.8	441.0	1454.0
T_8	7.0	36.0	630.1	594.1	1641.3	6.9	22.2	397.3	378.6	1270.7	6.7	35.1	557.5	522.4	1508.0
T_9	7.7	35.1	630.3	595.2	1640.0	7.0	22.8	407.3	389.3	1295.3	7.2	35.3	589.1	553.8	1507.3
SEm±	0.3	2.0	25.1	25.2	71.5	0.2	1.0	19.0	19.5	78.8	0.4	1.8	29.1	29.0	71.9
CD(p=0.05)	1.0	6.0	NS	NS	NS	0.7	3.1	NS	NS	NS	1.2	5.3	NS	NS	NS

Table 5. Effect of different treatments on H_2SO_4 K and Total K content in surface and sub-surface soil under rice based cropping system

Treatments	Rice-wheat				Rice-mustard				Rice-maize			
	H_2SO_4K		Total K		H_2SO_4K		Total K		H_2SO_4K		Total K	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	7956.0	8604.0	4044.7	1784.8	6135.3	6610.7	5615.6	3282.4	7520.7	8241.3	4525.5	2040.8
T_2	7991.3	8695.3	4228.3	2127.2	6274.7	6740.0	5653.9	3694.3	7554.0	8394.7	4493.9	2313.3
T_3	8322.7	8858.0	4194.9	2080.3	6506.7	6974.7	5629.3	3529.7	8542.0	9028.0	3533.3	2076.3
T_4	8568.0	9013.3	4189.3	2000.5	6957.3	7205.3	5622.6	3258.7	8706.7	9372.0	3689.7	2110.3
T_5	8667.3	9194.0	4562.0	2389.1	6968.0	7313.3	6153.2	3217.6	8754.7	9050.7	3934.0	2421.5
T_6	8798.0	9700.0	4608.1	2097.1	6823.3	7466.7	6445.5	3186.7	8788.0	9081.3	4308.4	2560.0
T_7	9435.3	9694.0	3595.1	1736.6	7200.0	7879.3	6059.2	3200.7	8773.3	8956.7	4159.3	2579.1
T_8	9753.3	9940.0	3813.3	1776.5	7218.7	7966.7	6329.9	3026.3	8850.7	8754.7	4350.1	2940.7
T_9	9770.7	9950.0	3973.5	1868.8	7308.0	7795.3	6071.6	3338.6	8854.7	228.0	4640.7	2561.7
SEm$\pm$	337.6	418.2	473.9	399.3	219.8	518.1	419.7	633.8	265.0	340.3	425.6	343.0
CD(p=0.05)	1012.2	NS	NS	NS	659.0	NS	NS	NS	794.4	NS	NS	NS

Table 6. Effect of different treatments on mineral fractions of potassium surface soil (0-15 cm) under rice based cropping system

Treatments	Rice-wheat				Rice-mustard				Rice-maize			
	Biotite K	Mica K	Musc K	Felds K	Biotite K	Mica K	Musc K	Felds K	Biotite K	Mica K	Musc K	Felds K
T_1	702.5	7423.2	6720.7	4044.7	646.5	5797.9	5151.3	5615.6	657.3	7053.3	6396.0	4525.5
T_2	733.9	7442.5	6708.7	4228.3	697.3	5936.0	5238.7	5653.9	759.6	7097.6	6338.0	4493.9
T_3	834.7	7739.3	6904.7	4194.9	708.7	6162.7	5454.0	5629.3	816.9	8072.3	7255.3	3533.3
T_4	818.9	7964.9	7146.0	4189.3	682.3	6573.6	5891.3	5622.6	851.5	8232.8	7381.3	3689.7
T_5	861.7	8061.7	7200.0	4562.0	689.6	6572.3	5882.7	6153.2	805.3	8248.0	7442.7	3934.0
T_6	873.3	8182.0	7308.7	4608.1	687.2	6423.2	5736.0	6445.5	831.7	8253.1	7421.3	4308.4
T_7	858.4	8815.7	7957.3	3595.1	715.9	6807.9	6092.0	6059.2	855.2	8284.5	7429.3	4159.3
T_8	877.5	9127.5	8250.0	3813.3	839.6	6822.9	5983.3	6329.9	853.9	8298.5	7444.7	4350.1
T_9	912.9	9146.5	8233.3	3973.5	843.3	6884.7	6041.3	6071.6	838.4	8270.4	7432.0	4640.7
SEm$\pm$	40.5	340.0	347.2	473.9	31.6	218.0	215.9	419.7	35.8	268.0	246.3	425.6
CD(p=0.05)	121.3	1019.2	1040.8	NS	94.9	653.6	647.3	NS	107.5	803.4	738.4	NS

Table 7. Effect of different treatments on mineral fractions of potassium of sub-surface soil (0-15 cm) under rice based cropping system

Treatments	Rice-wheat				Rice-mustard				Rice-maize			
	Biotite k	MicaK	Musc K	FeldsK	BiotiteK	MicaK	Musc K	FeldsK	Biotite k	MicaK	Musc K	FeldsK
T_1	829.3	8065.3	7236.0	1784.8	689.3	6275.3	5586.0	3282.4	794.8	7733.5	6938.7	2040.8
T_2	902.4	8137.1	7234.7	2127.2	714.4	6399.1	5684.7	3694.3	804.9	7875.6	7070.7	2313.3
T_3	829.9	8267.2	7437.3	2080.3	766.0	6626.0	5860.0	3529.7	898.3	8229.6	7631.3	2076.3
T_4	851.9	8405.2	7553.3	2000.5	804.5	6821.9	6017.3	3258.7	842.8	8852.1	8009.3	2110.3
T_5	914.8	8576.8	7662.0	2389.1	759.2	6909.2	6150.0	3217.6	841.7	8520.4	7678.7	2421.5
T_6	1041.7	9077.1	8035.3	2097.1	797.3	7065.3	6268.0	3186.7	816.0	8481.3	7665.3	2560.0
T_7	995.9	9067.2	8071.3	1736.6	819.7	7445.1	6625.3	3200.7	981.2	8483.9	7502.7	2579.1
T_8	1011.2	9309.9	8298.7	1776.5	873.3	7569.3	6696.0	3026.3	950.5	8197.2	7246.7	2940.7
T_9	1009.7	9319.7	8310.0	1868.8	888.0	7388.0	6500.0	3338.6	918.3	8638.9	7720.7	2561.7
SEm±	79.6	409.8	424.2	399.3	74.4	513.9	546.5	633.8	90.8	336.6	377.5	343.0
CD(p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 8. Correlation between soil properties and different fractions of potassium of surface soil

Soil Properties/ K Fractions	OC	CEC	WSK	AAK	HNO_3K	HClK	NEK	H_2SO_4K	Total K
Rice-wheat cropping system									
OC	1.000	0986**	0.885**	0.972**	0.931**	0.921**	0.911**	0.965**	0.920**
CEC	0.986**	1.000	0.870**	0.962**	0.895**	0.896**	0.872**	0.953**	0.922**
WSK	0.885**	0.829**	1.000	0.858**	0.911**	0.905**	0.897**	0.797*	0.877**
AAK	0.972**	0.975**	0.858**	1.000	0.911**	0.885**	0.877**	0.927**	0.843**
Rice-mustard cropping System									
OC	1.000	0.946**	0.876**	0.954**	0.851**	0.842**	0.949**	0.939**	0.911**
CEC	0.946**	1.000	0.903**	0.961**	0.893**	0.886**	0.923**	0.945**	0.913**
WSK	0.868**	0.850**	1.000	0.939**	0.891**	0.885**	0.784*	0.920**	0.920**
AAK	0.949**	0.937**	0.939**	1.000	0.949**	0.943**	0.885**	0.987**	0.963**
Rice-maize cropping system									
OC	1.000	0.951**	0.936**	0.865**	0.844**	0.823**	0.980**	0.871**	0.921**
CEC	0.951**	1.000	0.947**	0.918**	0.883**	0.859**	0.913**	0.831**	0.979**
WSK	0.936**	0.939**	1.000	0.777*	0.893*	0.886**	0.943**	0.875**	0.955**
AAK	0.865**	0931**	0.777*	1.000	0.818*	0.779*	0.777*	`0.600	0.901**

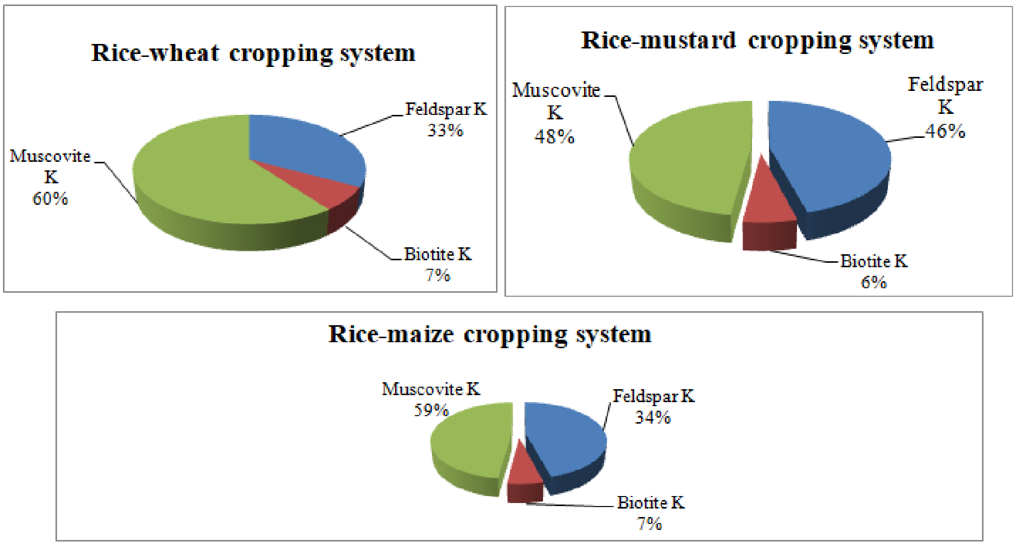
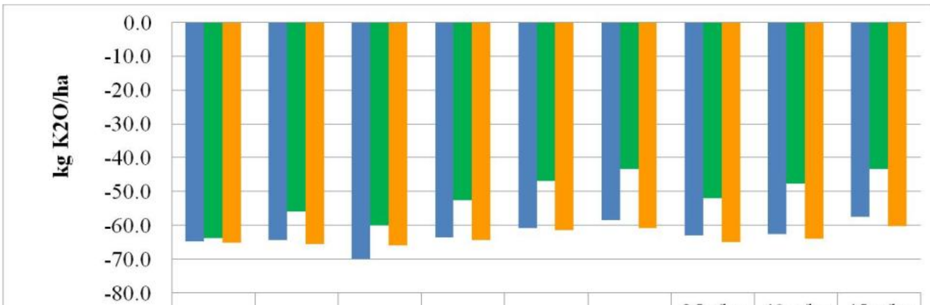


Fig. 2. Contribution of different K minerals towards total K in surface soil



	Control	FP	GRD	35 q/ha	40 q/ha	45 q/ha	35q/ha IPNS	40 q/ha IPNS	45 q/ha IPNS
Rice-wheat	-64.7	-64.2	-69.9	-63.4	-60.8	-58.5	-62.8	-62.5	-57.4
Rice-mustard	-63.7	-55.9	-60.0	-52.5	-46.7	-43.3	-51.9	-47.6	-43.2
Rice-maize	-65.2	-65.4	-65.9	-64.2	-61.3	-60.7	-64.8	-63.9	-60.2

Fig. 3. Apparent K balance (Kg K_2O ha^{-1}) in soil after seven year continuous fertilization under rice based cropping system

Apparent K balance = (Initial K + K input) – (K uptake + av. K in PHS)

The total moving of K by the crop exceeded the content of total K application to the soil in all the treatments showing a net negative K balance [31-34]. The treatment with application K fertilizer, especially 150 per cent NPK and NPK along with FYM sustained higher K supplying capacity match with imbalance nutrition reported by Das et al. [22,35-38].

4. CONCLUSION

Various fractions of K were higher in surface as compared to sub-surface soil. Continuous application of STCR-based fertilizer with 5 t ha^{-1} compost for yield target 45 q ha^{-1} treatment improve the status of K fractions and apparent K balance except total K in soil compare to other treatments. Thus, application of STCR based NPK along with compost will help in mitigating the K deficiency and improves the K pools in soils.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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