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Soil Potassium Fractions as Influenced by Integrated Fertilizer Application Based on Soil Test Crop Response under Maize-Wheat Cropping Systems in Acid Alfisol

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Abstract

Field experiments were conducted during 2014–15 to 2015–16 at the Experimental Farm of Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, HP as a part of long-term fertilizer experiment initiated in *kharif*, 2007 in a maize-wheat sequence. The experiment consisted of eight treatments viz., (1) control; (2) general recommended dose; (3) soil test based; (4) farmers' practice; (5) target yield of 25 and 30 for rabi and kharif, respectively without FYM; (6) target yield of 25 and 30 for *rabi* and *kharif*, respectively with FYM @ 5 t ha^{-1} (7) target yield of 35 and 40 q ha^{-1} for *rabi* and *kharif*, respectively without FYM; (8) target yield of 35 and 40 q ha^{-1} for *rabi* and *kharif*, respectively with FYM @ 5 t ha^{-1}) which were replicated thrice in a randomized block design. The fertilizer adjustment equations were developed based on target yield concept and accordingly nutrient doses were calculated. The results revealed that soil available K was significantly increased in both the target yields with IPNS over general recommended dose and soil test based treatments. The different forms of potassium i.e. water soluble K, exchangeable K and non- exchangeable K were highest under STCR (IPNS) treatment for target yield of 35 q ha^{-1}. The status of non-exchangeable potassium was significantly inferior in unfertilized plots in comparisons to all other treatments. Regression analysis showed that exchangeable K was the most important variable contributing about 94% in the total variation in available- K.

1. Introduction

Efficient nutrient management is one of the key management strategies in current agriculture to achieve required food production to feed rapidly growing population. Potassium has long been a neglected nutrient in Indian agriculture (Sanyal, 2014). Potassium requirement of crops are in general identical to nitrogen. Over extraction of K from soil due to continuous mismatch between crop demand and external supply results in depletion of K reserve. Balanced application of fertilizers is needed for sustainable crop production and maintenance of soil health. Long term fertilizer experiments have shown a comparatively better yield of crops when balanced NPK fertilizers are used in comparisons to NP use only (Dutta et al., 2015).

Potassium exists in soil in different forms *viz.,* water soluble, exchangeable K, non exchangeable K (fixed K) and mineral K. In India, the current K fertilizer recommendations based on assessment by neutral normal NH$_4$OAc extractable K (pH 7) is commonly followed (Rao, 2014). Equilibrium exists among different forms that affect level of K in soil solution at particular time and availability of K in plants. The distribution of these forms in soils is important in understanding the conditions controlling their availability to growing crops. Knowledge and understanding of K dynamics in soil proves to be the best approach in arriving at fertilizer recommendation for crops. Soil characteristics, management practices, plant type and environmental conditions greatly influenced availability of each form of K in soil. Knowledge and understanding of K dynamic in soil proves to be the best approach in arriving at fertilizer recommendation for crops.

Application of fertilizers based on soil test nutrient availability and crop response to fertilizer applied for specific yield target is considered as a soil and fertilizer based precision farming strategy to achieve target food grain production as well as reducing environmental degradation. The present study was, therefore, under taken to assess the effect of soil test crop response based fertilizer recommendations on soil potassium dynamics under maize-wheat cropping system.

2. Materials and Methods

2.1. Field experiments

The present study was undertaken as a part of long-term fertilizer experiment initiated in *kharif*, 2007 in a maize-wheat sequence at the Experimental Farm of Department of

Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, HP. The experimental farm is situated at 32° 6′ N latitude and 76° 3′ E longitude at an elevation of 1290 m above mean sea level. The climate of the experimental site is characterized as wet-temperate, with mild summers and cool winters. Taxonomically, the soil of the study area falls in the order Alfisol and sub group Typic Hapludalf (Verma, 1979). The soil of the experimental site at initiation of experiment was acidic in reaction and silty clay loam in texture. The experiment was laid out in randomized block design (RBD) with eight treatments (Table 1).

Table 1: Detail of treatments

Treat-ment	*Kharif* maize	*Rabi* wheat
T_1	Control	Control
T_2	Farmers' practice i.e. 25% of general recommended dose N+5 t ha⁻¹ FYM on dry weight basis	Farmers' practice i.e. 25% of general recom-mended dose N+5 t ha⁻¹ FYM on dry weight basis
T_3	General Recommended Dose (GRD) i.e. 120, 60, 40 kg ha⁻¹ N, P_2O_5 and K_2O, respectively)	General Recommended Dose (GRD) i.e. 120, 60, 30 kg ha⁻¹ N, P_2O_5 and K_2O, respectively)
T_4	Soil test based fertilizer application	Soil test based fertilizer application
T_5	NPK dose for target 30 q ha⁻¹	NPK dose for target 25 q ha⁻¹
T_6	NPK dose for target 30 q ha⁻¹ with FYM @ 5 t ha⁻¹	NPK dose for target 25 q ha⁻¹ with FYM @ 5 t ha⁻¹
T_7	NPK dose for target 40 q ha⁻¹	NPK dose for target 35 q ha⁻¹
T_8	NPK dose for target 40 q ha⁻¹ with FYM @ 5 t ha⁻¹	NPK dose for target 35 q ha⁻¹ with FYM @ 5 t ha⁻¹

Nutrients doses (kg ha⁻¹) were calculated from the fertilizer adjustment equations for targeting yield of maize and wheat crop:

Maize	Wheat
FN=5.88 T-0.23 SN-0.93 ON	FN=5.27 T-0.25 SN-1.06 ON
FP_2O_5 =4.87 T-1.22 SP-0.81 OP	FP_2O_5=4.13 T-0.38 SP-0.98 OP
FK_2O=3.66 T-0.49 SK-0.51 OK	FK_2O=2.87 T-0.15 SK-0.55 OK

In above equations, FN, FP_2O_5, FK_2O are doses of N, P_2O_5 and K_2O, respectively in kg ha⁻¹. T is yield target (q ha⁻¹), SN, SP and SK are soil available N, P and K, respectively in kg ha⁻¹. ON, OP and OK are N, P and K that were supplied through

FYM kg ha⁻¹, respectively.

2.2. Soil sampling

Plot-wise composite soil samples (0-0.15 m depth) were collected from each plot after harvest of wheat crop (2014-15 and 2015-16). The soil samples were dried in shade, ground in pestle mortar, passed through 2 mm sieve and subjected to laboratory analysis

2.3. Analysis of soil samples

Soil samples were analyzed for available K using 1N Ammonium Acetate (pH 7) given by Black (1965). Different fractions of potassium *viz.*, water soluble, exchangeable and non exchangeable potassium were determined as per the procedure listed below:

a) Water-soluble K: Water-soluble K was extracted by shaking the soil water suspension in the ratio of 1:5 for one hour then filtered, and K was determined (Grewal and Kanwar, 1966).

b) Exchangeable K: 50 ml of 1N Ammonium acetate was added to ten grams of soil taken in a 125 ml flask, thoroughly mixed and kept overnight. Then the soil was filtered, washed with neutral 1 N NH_4OAc until volume of 100 ml was obtained and K was determined. The amount of exchangeable K was calculated by subtracting water soluble K from K extracted with neutral 1N NH_4OAc (Merwin and Peeech, 1950).

c) Non exchangeable K: Twenty five ml of 1N HNO_3 was added to 2.5 g of soil taken in 100 ml beaker, kept for 15 minutes, the beaker was covered with watch glass and then boiled for 10 minutes. The soil was then filtered into a 50 ml of volumetric flask washed with 0.1 N HNO_3 until the filtrate was brought to volume and quantity of K was determined. The non exchangeable K was calculated by subtracting K extracted with neutral normal NH_4OAc from K extracted in hot 1N HNO_3 (Sutton and Seay, 1958).

2.4. Statistical analysis

The data generated from the field and laboratory studies were subjected to statistical analysis using the technique of analysis of variance for randomized block design for the interpretation of results as described by Gomez and Gomez (1984).

3. Results and Discussion

3.1. Available K

After wheat harvest (*rabi*, 2014-15), the available K significantly increased by 21.4% in farmers' practice over control (Table 2). The treatment target yield of 25 and 35 q ha⁻¹ with FYM significantly improved the available K content by 1.5 and 3.3 per cent over the same treatment without FYM. During second year *i.e.* after harvest of wheat (*rabi,* 2015-16), the lowest values of available K in T_1 was significantly inferior over all other treatments. Farmers' practice and general recommended dose treatments increased available K content in soil by 31.3 and 32.8% over control. The treatment target yield of 25 and 35 q ha⁻¹ without FYM increased the available

Table 2: Effect of prescription based fertilizer application on available K status of soil (kg ha^{-1})

Treatment	K	
	2014-15	2015-16
T_1: Control	210	198
T_2: Famers' Practice	255	260
T_3: General Recommended dose	265	263
T_4: Soil Test Based	268	265
T_5: Target yield 25 q ha^{-1}	270	271
T_6: Target yield 25 q ha^{-1} with FYM @ 5 t ha^{-1}	272	275
T_7: Target yield 35 q ha^{-1}	276	273
T_8: Target yield 35 q ha^{-1} with FYM @ 5 t ha^{-1}	284	282
CD p=0.05	12.0	12.1

K content by 3.0 and 3.8% over general recommended dose.

The available K content in control was lowest due to continuous cropping and no addition of K from external sources. This reduction of soil available K in comparison to the initial value might be due to continuous mining of the soil native pool that also caused reduction in crop yield (Katkar et al., 2011). Tiwari et al. (2013); Ram et al. (2016) reported that available K content improved when farmyard manure was added with inorganic fertilizers. Increase in available potassium under STCR approach involving IPNS might be due to direct addition of available K to soil as well as reduction of potassium m fixation and release of potassium due to interaction of organic matter with clay (Katkar et al., 2011).

3.2. Water soluble potassium

The lowest value in control where no inorganic fertilizers or manures were applied was statistically at par with farmers' practice (after wheat harvest, *rabi*, 2014–15). Application of general recommended dose significantly increased the water soluble K by 20.5 and 15.0% over control and farmers' practice, respectively. The STCR (IPNS) approach for target yield of 25 and 35 q ha^{-1} significantly increased the water soluble K content by 7.8 and 10.6% over the same treatment without FYM.

However, after harvest of wheat (*rabi,* 2015-16), the highest value in T_8 was at par with water soluble K in T_7. The treatment under STCR approach for target yield of 25 and 35 q ha^{-1} without FYM increased the water soluble K content by 6.3 and 15.2% over general recommended dose.

The water soluble potassium increased significantly in treatments where inorganic fertilizers alone or in combination with FYM were applied over control. In farmers' practice, higher water soluble K content over control might be due to additional supply of K from FYM. Addition of K by potassium fertilizer and organic manures which contains significant amount of K released the water soluble K in soil. Similar findings were reported by Sawarkar et al. (2013), Habib et al. (2014) and Meena and Biswas (2014).

3.3. Exchangeable potassium

The lowest value of exchangeable K in control was statistically inferior in comparisons to all other treatments (Table 3). During 2014–15, the exchangeable K in farmers' practice was significantly enhanced by 18.2% over control. Similarly,

Table 3: Effect of prescription based fertilizer application on soil potassium fractions (mg kg^{-1})

Treatment	Water soluble K		Exchangeable K		Non exchangeable K	
	2014- 15	2015-16	2014-15	2015-16	2014-15	2015- 16
T_1: Control	12.7	11.7	77	75	452	452
T_2: Famers' Practice	13.3	13.0	91	98	459	454
T_3: General Recommended dose	15.3	15.8	100	98	492	496
T_4: Soil Test Based	15.5	16.3	106	104	493	493
T_5: Target yield 25 q ha^{-1}	16.7	16.8	106	106	495	496
T_6: Target yield 25 q ha^{-1} with FYM @ 5 t ha^{-1}	18.0	17.8	107	107	493	497
T_7: Target yield 35 q ha^{-1}	18.8	18.2	109	111	497	498
T_8: Target yield 35 q ha^{-1} with FYM @ 5 t ha^{-1}	20.8	20.0	111	112	498	499
CD p=0.05	1.5	1.8	4.7	5.4	6.9	7.5

exchangeable K was significantly increased under the treatment involving general recommended dose and soil test based by 29.9 and 37.7% over control, respectively. The exchangeable K under the STCR (IPNS) approach for target yield of 25 and 35 q ha^{-1} was slightly increased by 0.9 and 1.8 per cent over the corresponding treatment without FYM.

Similarly, after wheat harvest (2015–16), its value under the treatment general recommended dose and soil test based was significantly improved in soil by 30.7 and 38.7% over control, respectively. The treatment under STCR approach

for target yield of 25 and 35 q ha^{-1} without FYM increased the exchangeable K content by 8.2 and 13.3% over general recommended dose. The exchangeable K under IPNS treatment for target yield 25 and 35 q ha^{-1} was at par with the same treatment without FYM.

In both the years, the content of exchangeable potassium was higher under treatments where inorganic fertilizers alone or in combination with FYM were applied over control which might be due to reduction in potassium fixation caused by repeated addition of manures along with potassic fertilizers (Sepehya, 2011). The additional supply of organic manures increased the CEC of the soil, which can hold more exchangeable potassium and convert potassium from non exchangeable form to exchangeable form, consequent to mass action effect (Black, 1968). These results were also reported by Sawarkar et al. (2013); Meena and Biswas (2014).

3.4. Non exchangeable potassium

Application of FYM along with inorganic fertilizers for target yield 35 q ha^{-1}, which recorded highest non exchangeable K was at par with all treatments except T_1 (control) and T_2 (farmers' practice). Farmers' practice also recorded significant

enhancement of 1.5% over control. The data further revealed that application of general recommended dose and soil test based increased the non exchangeable K over control by 8.8 and 9.1 %, respectively (Table 3). However, after wheat harvest (*rabi*, 2015-16), the lowest value in control was statistically at par with farmers' practice. All other treatments significantly increased non- exchangeable K over unfertilized plots. This might be attributed to the regular application of inorganic fertilizers which suggest that current dose of fertilizer application was sufficient to sustain K fertility. Applications of FYM under STCR approach reduces the amount of inorganic fertilizers and maintain soil fertility. These results were in conformity with those of Meena and Biswas (2014), Jatav et al. (2010) and Sharma et al. (2013).

3.5. Relationship of different forms of potassium

All the fractions of potassium were positively and significantly correlated with each other (Table 4). The step- wise regression analysis (Table 5) showed that exchangeable K was the most important variable contributing about 94 per cent in the total variation in available- K.

Table 4: Correlation coefficients (r) of different potassium fractions

2014-15			
	Ws-K	Ex- K	Non- ex K
Ex- K	0.790**		
Non- ex K	0.765**	0.901**	
Available K	0.773**	0.938**	0.823**
2015-16			
	Ws-K	Exc- K	Non- ex K
Ex- K	0.814**		
Non- ex K	0.840**	0.746**	
Available K	0.771**	0.943**	0.739**

**Significant at (*p*=0.01) level of significance; Ws- K: water soluble K; Ex- K: exchangeable K; Non- ex K: non- exchangeable K

Table 5: Multiple regression equations indicating relationship between available K and different fractions of potassium

Regression Equation	R[2]
2014-15	
Available K= 71.70 + 0.936** Exch. K	0.9377**
2015-16	
Available K= 46.14 + 0.943** Exch. K	0.9430**

**Significant at (*p*=0.01) level of significance

4. Conclusion

STCR (IPNS) approach of fertilizer application recorded relatively higher available K and all fractions of K. This indicated the maintenance of soil potassium due to soil test based fertilizer recommendation under IPNS. Non- exchangeable

potassium status of soil was not influenced significantly with the use of chemical fertilizers alone or in combination with organics. All treatments were statistically at par among themselves except farmers' practice and control which show decline in its content. Exchangeable K was the important fraction of potassium contributing towards available K.

5. Acknowledgement

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