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Vertical Distribution of Different Fractions of Soil Potassium of Some High Mining Areas of North-Eastern Region of Haryana, India

Koustav Mondal, Ramkala

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Abstract As plant available potassium is highly influenced by other forms of soil potassium, in agricultural point of view, vertical distribution of different forms of potassium has a great significance. Influence of high mining and differential potassium fertilization showed effect on soil profile potassium fraction distribution. Eight soil profile samples from each of Ambala, Panchkula and Yamunanagar districts at depth from 0–15, 15–30, 30–60 and 60–90 cm were collected to study the distribution of potassium along the soil profile. The distribution of different forms of potassium i.e. water soluble, exchangeable, non-exchangeable and K varied from 7 to 42 mg/kg, 23 to 198 mg/kg, 111 to 749 mg/kg and 1.24% to 2.13% respectively. Almost all the forms of soil potassium were found highest in the top soil layer and a trend of decreasing depth wise. Organic carbon and CEC showed positive correlation with all the forms of K and which were found to be positively correlated with each other in north-eastern region of Haryana.

Keywords Vertical distribution, Potassium forms, Water soluble potassium, Exchangeable potassium, Total potassium.

Introduction

Potassium is the seventh most abundant mineral in the earth crust averaging about 2.59%. Potassium is one of the najor elements. Potassium is the key element in soil chemistry and soil fertility because large portion of potassium is present in soil as a part of crystalline structure of primary and secondary minerals. Importance of potassium in Indian agriculture has increased with intensification of agriculture. The gap between removal of K and its application to crop is widening. It is therefore imperative to understand dynamics of K in soil and application of K-fertilizer according to needs of crops to provide balanced nutrition, harvest good yields and maintain the potassium status of soil. Soil potassium exists in dynamic equilibrium in four forms that is water soluble, exchangeable, non-exchangeable and lattice potassium. Water soluble and exchangeable potassium are important for plant and microbial growth. Among the

K. Mondal*
Research Scholar,
Department of Agricultural Chemistry and Soil Science,
Bidhan Chandra Krishi Viswavidyalaya,
Mohanpur 741252, West Bengal, India

Ramkala
Former Soil Scientist,
Department of Soil Science,
CCS Haryana Agricultural University,
Hisar 125004, Haryana, India
e-mail : koustavmondal2007@gmail.com
*Correspondence

Table 1. Basic soil chemical properties of north-eastern region of Haryana (Ambala, Panchkula and Yamunanagar districts).

Soil depth (cm)	pH [1:2]	EC [1:2] dSm^{-1}	CEC (cmol (p+)/kg)	OC (%)	$CaCO_3$ (%)
0–15	8.1	0.3	12.3	0.33	0.3
15–30	8.2	0.3	11.3	0.27	0.3
30–60	8.2	0.2	10.0	0.21	0.2
60–90	8.3	0.2	9.1	0.16	0.2

Table 2. Range of different forms of potassium distributions in Ambala, Panchkula and Yamunanagar districts.

Soil depth (cm)	Forms of potassium: Water soluble (kg/ha)	Exchangeable (kg/ha)	Non-exchangeable (kg/ha)	Total (%)
Ambala				
0–15	11.8-41.8	38.3-198.3	260-749.4	1.34-1.86
15–30	11.3-33.8	33.8-157.8	199.5-530	1.31-1.75
30–60	10-28.3	27.3-146.5	183.1-492.2	1.28-1.76
60–90	7.8-25	22.8-112.3	148.1-442.3	1.24-1.67
Panchkula				
0–15	11.3-17	55.3-133	258.4-487.6	1.43-1.96
15–30	10.5-16	49-116	186.2-512.9	1.52-1.86
30–60	10.3-14.3	39-111.8	144.3-536.4	1.46-1.89
60–90	8.5-12	26.5-144.5	111.3-679.2	1.37-1.75
Yamunanagar				
0–5	11.8-16.3	37.5-113.3	213.8-475.7	1.52-2.13
15–30	10.3-18.8	28.3-100.8	158.2-423.1	1.47-2.03
30–60	8.8-14.8	27.5-101	141.5-414.1	1.52-1.95
60–90	7-12.8	23.8-101.5	128.3-395.9	1.48-1.99

different forms of K, the largest amount of K is present as structural element (lattice) of minerals. Whenever there is any depletion of potassium in soil solution, due to leaching or erosion or uptake by plants then different forms of potassium contribute to the soil solution. Pasricha [1] stated that the ease with which K is released from non-exchangeable source is an index of the ability of soil to supply K to crop plants not receiving any potassium fertilizer. But in the absence of adequate K fertilization, significant depletion of soil K reserves takes place and there is a probability of yield loss and higher economic risk for farmers. The releasing behavior of potassium depends on the interactions of soil properties and hence it is important to have knowledge of all the forms of potassium present in soil for the relevance in assessing the availability of potassium to crop and formulation of fertilizer recommendations. Sparks [2] stated that potassium is fixed because of the binding forces between K and clay surfaces are greater than hydration forces between individual K ions. This results in partial collapse of the crystal structures causing physical entrapment of K. This makes K release a slow diffusion controlled process. However, the concentration of K^+ in the soil solution needs to be quite low before non-exchangeable or fixed K can be released to soil solution.

Dahiya and Shanwal [3] investigated in soils of Haryana and reported potassium content of degraded mica in soils of Haryana has gone down from 10 to 5% as a result of intensive cultivation and low potassium fertilization. Therefore, keeping in view of above mentioned facts the present study was undertaken to investigate the vertical distribution of potassium in soils of north-eastern region of Haryana (Ambala, Panchkula and Yamunanagar districts).

Materials and Methods

Collection and preparation of soil samples

For the investigation of vertical distribution of potassium in north-eastern region of Haryana soil profile samples from each of Ambala, Yamunanagar and Panchkula districts, eight profile samples from 0–15, 15–30, 30–60 and 60–90 cm depth were collected. These samples were air dried, ground to pass through a 2 mm sieve and analyzed for different physico-chemical properties and different forms of potassium.

Soil physico-chemical properties

Soil pH and electrical conductivity (1:2 soil water suspension)

pH and electrical conductivity were determined by

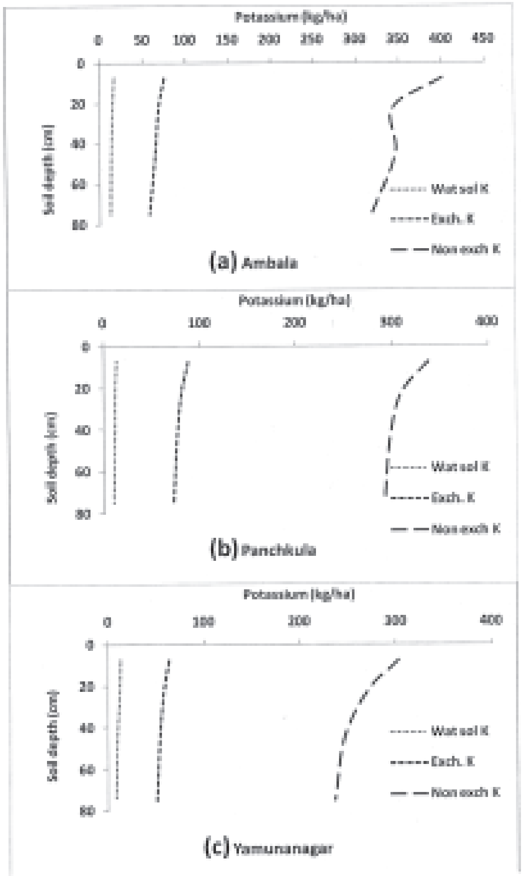

Fig. 1. Vertical distribution of different forms of potassium in (a) Ambala, (b) Panchkula and (c) Yamunanagar districts of Haryana.

the standard procedure as described by Richards [4].

Organic carbon

Organic carbon determined according to the Wet Digestion Method [5].

Cation exchange capacity : [cmol (p^+)/kg]:

Cation exchange capacity of each soil profile sample was determined by sodium acetate method [6].

Table 3. Correlation coefficients of different K forms with soil properties. **Significant at 1% level, *Significant at 5% level. n=96.

Forms of potassium	pH	EC	CEC	OC	$CaCO_3$
WS-K	-0.126	0.873**	0.539**	0.173	0.159
EX-K	-0.372**	0.108	0.299**	0.465**	0.016
NEX-K	-0.129	0.259*	0.257*	0.428**	0.252*
Total-K	-0.398**	0.019	0.372**	0.474**	0.005

Calcium carbonate

Calcium carbonate of the soil was determined by standard method [7]. 10.0 gram of soil in 200 ml distilled water was titrated with 0.5 N H_2SO_4 in the presence of bromothymol blue and bromocresol green indicators.

Distribution of different forms of soil potassium

Water soluble potassium

Water soluble potassium was determined in 1 : 2.5, soil: water ratio.

Exchangeable potassium

Neutral Normal Ammonium Acetate extractable method was adopted for the estimation of exchangeable K [6]. The actual exchangeable K was determined by subtracting the value of water soluble K from the NH_4OAc extractable K.

Non-exchangeable potassium

Non-exchangeable potassium was determined as per the standard procedure [8], according to which 25 ml 1N HNO_3 was added to 2.5 g soil and boiled gently for 10 minutes and filtered. Washed the soil with four 15 ml portion of 0.1N HNO_3 and dilute the solution to 100 ml. The NH_4OAc extracted K was then subtracted from the HNO_3 extracted K to calculate the amount of non-exchangeable potassium in soil.

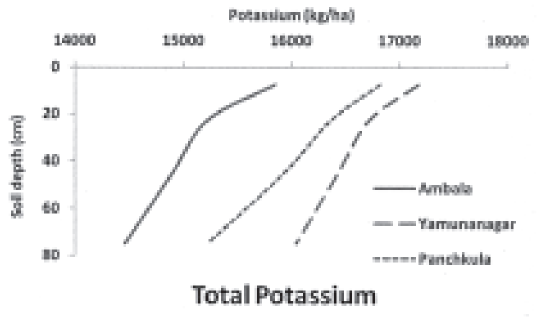

Fig. 2. Vertical distribution of total soil potassium in Ambala, Panchkula and Yamunanagar districta of Haryana.

Total potassium

Total potassium was determined by following digestion of soil with 48% HF and 72% $HClO_4$ solution in platinum crucible at 200–225°C on a sand bath. The content was dissolved by adding 5 ml of 6N HCl and boiled on a hot plate [6].

The amount of K in each of the above extracts was determined with the help of flame photometer.

Relationship between different forms of potassium and soil properties

Correlations between different forms of K and soil properties and among different forms of K were worked out by the procedure described earlier [9].

Results and Discussion

Eight soil profiles from each of Ambala, Yamunanagar and Panchkula districts, at depths from 0–15, 15–30, 30–60, and 60–90 cm were collected. These samples were air dried, ground and passed through a 2 mm sieve and analyzed for different physico-chemical properties and different forms of potassium.

Physico-chemical properties of profile soil

Basic soil properties of the experimental area are presented in Table 1. The pH of the soil of the three districts was found to be alkaline in reaction. Increase in pH with increase in soil depth was observed in general. Low electrical conductivity showed that the salt content of these soils was negligible and good for the crop growth. Electrical conductivity in general did not followed any specific trend, but in some soil profile like Chhapra, Bulane, Montabra, Devdhar soil profiles it decreased with increase in depth. Calcium carbonate content in the soil profile was very low but some of the soil profiles like Fatehgarh (Yamunanagar), Bhura Mazra (Ambala) contained calcium carbonate along the whole soil profile, but it did not follow any specific trend with soil depth. Organic carbon content of the profile soils follow a definite trend of decreased with increasing of soil depth. But some of the soil profiles like at Bhuramajra in Ambala did not follow the same pattern. Cation exchange capacity of the profiles decreased with the increase of the depth of the soil profile.

Vertical distribution of different forms of potassium

Water soluble potassium

Water soluble potassium in the soil profiles ranged from 7 mg/kg in Sadora village in Yamunanagar district to 42 mg/kg in Bulane village in Ambala (Table 2) and it contributed to the tune of 0.05 to 0.25% of the total potassium. This amount seemed to be quite inadequate to meet the crop requirements of potassium. Similar results were found earlier [10] in some soils of West Bengal.

Depth wise very low water soluble potassium content was found (Fig. 1). Most of the soil profiles show the general trend of decreasing water soluble potassium with increasing depth. But some soil profiles did not follow the same rule. Relatively higher values of water soluble potassium in the sub-surface horizons in those profiles could be attributed to relatively higher amount of organic matter along the profile and might be due to more removal of potassium by the crop from the upper layers of the soil profile. These results are in agreement with earlier results [11].

This form of K was found positively and significantly correlated (Table 3) with EC (r=0.873) and CEC

Table 4. Correlations among different forms of potassium. **Significant at 1% level, *Significant at 5% level. n=96.

Forms of potassium	WS-K	EX-K	NEX-K	TOTAL-K
WS-K	1.000**			
EX-K	0.128	1.000**		
NEX-K	0.244*	0.793**	1.000**	
TOTAL-K	0.085	0.614**	0.279**	1.000**

(r=0.539) but negatively correlated with pH of the soils. It is also positively correlated with organic carbon and calcium carbonate. This form of potassium was found to be positively correlated with all the other forms of potassium (Table 4). It showed a significant correlation with non-exchangeable potassium (r=0.244). Similar result was also reported earlier [12].

Exchangeable potassium

The exchangeable potassium content represents the fraction of potassium which is adsorbed on external and accessible internal surfaces. Exchangeable potassium content of these three district soils ranged from 33 mg/kg at Saha in Ambala district to 198 mg/kg at Danora in Ambala district (Table 2) and contribution towards total K ranged from 0.2 to 1.06%. Low to lower medium oxidisable organic carbon content and light texture of the soil profile explains the lower content of exchangeable potassium. These results are in agreement with earlier report [13].

No general trend of this form of potassium was observed with soil profile depth. But some profiles showed decreasing pattern with increasing soil profile depth which resulted a average decreasing trend of this form of potassium with increasing soil depth (Fig. 1). Similar results were also reported earlier [14].

The values of correlation coefficients of exchangeable potassium with soil properties (Table 3) showed a positive and significant correlation with CEC (r=0.299) and organic carbon content (r=0.465) but a significant and negative correlation with pH values of the soil profiles. Chand and Swami [15] also observed similar results. This form of potassium was found to be positively correlated with all the other forms of potassium (Table 4). It showed a significant correlation with non-exchangeable (r=0.793) and total potassium (r=0.614) content of the profile soils. Good correlations of this form of K with other forms of K indicate that the different forms were in equilibrium with each other. Similar findinds were also reported earlier [16, 17].

Non-exchangeable potassium

The non-exchangeable potassium content varied from 111 mg/kg at Mantora in Panchkula to 749 mg/kg at Danora in Ambala (Table 2). Percent contribution of non-exchangeable potassium towards total potassium ranged from 0.76 to 4.03%. Many profiles showed a decreasing pattern of this form of potassium with soil profile depth but in some profile soils it did not the same rule, which may be the indication of active pedoturbation processes in these pedons. These results are in agreement with earlier report [14]. But Sharma and Sharma [16] found much higher non-exchangeable potassium in the potato growing soils of Punjab.

This form of soil potassium happened to accumulate in top soil layer (Fig. 1) which decreased sharply in the immediate lower layer and then the decreasing rate was found reduced markedly. This trend was found almost in all the districts.

This form of potassium showed positively and significantly correlated with electrical conductivity (r=0.259), CEC (r=0.257), organic carbon (r=0.428) and calcium carbonate (r=0.252) whereas negatively correlated with pH (r= -0.129) of the soils (Table 3). Non-exchangeable potassium showed a positive correlation with all the forms of potassium (Table 4). These results are in agreement with earlier report [18].

Total potassium

The amount of total potassium in different soil profiles of three districts ranged from 1.24% to 2.13% of soil with a mean value of 1.59% of soil (Table 2). Saini and Grewal [19] also found similar results while investigation different forms of potassium and their interrelationship in some soils of Haryana. Highest total potassium was found at mulepur soil profile in Yamunanagar district and least at Saha soil profile in Ambala district. Relatively higher amount of total potassium in this region may be due to high amount of illite minerals. A similar result of surface soil total potassium was also found earlier [20].

Total potassium content was found highest in Yamunanagar district followed by Panchkula and Ambala (Fig. 2). The total potassium content in the soil profile followed a general trend of decreasing with increasing of profile depth. It may be due to the presence of sufficient potash bearing primary minerals in the soils which were developed *in situ*. Some profiles like Bhuramajra (Ambala), Bhoria (Panchkula), Sadora, Milk mazra (Yamunanagar) did not follow the same rule.

The total potassium content was found to be positively and significantly correlated with CEC and organic carbon content of the soil whereas negatively correlated with pH of the soil (Table 3). It was also observed that generally light textured soil contain fewer amounts of total potassium which reveals that finer fractions of the soils are primary source of potassium in the north-eastern region Haryana. Chand and Swami [15] also observed positive correlation among total potassium, CEC and organic carbon content of the soil. Total potassium showed a high and significant correlation with exchangeable (r=0.614) and non-exchjangeable (r=0.279) potassium (Table 4). Similar results were also found by Kaskar et al. [12].

Conclusion

Organic carbon and CEC showed positive correlation with all the forms of K which indicates that these physico-chemical properties have influence on distribution of different forms potassium. All the forms of K were found to be positively correlated which is a reflection of their dynamic equilibrium among themselves. Different forms of potassium in the soil profiles were generally found to decrease with the increase of the depth of soil. The high mining crop production system of north-eastern region of Haryana stimulated the depletion of soil potassium, thereby, demanding higher potassium fertilization. Further study on correlation of potassium reserve pool and clay mineralogy will help to predict potassium supplying capacity of the soil and to recommend fertilization rate.

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