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Vertical distribution of potassium fractions and their relationship with soil properties in different textured soils of Haryana

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Abstract
Distribution of different forms of potassium in soils in Haryana was studied by exposing profiles. Most of the soils were light in texture and ranged from sand to clay. They were neutral to slight alkaline in nature. The organic carbon in Kaul soil varied from 0.19 to 0.54%. In majority of the soils, the organic carbon content showed a decreasing trend with depth. The distribution of the different forms of the potassium i.e. water soluble, exchangeable, non-exchangeable and total potassium in these soils ranged from 6.26 to 24.93 kg ha^{-1}, 28.09 to 160.25 kg ha^{-1}, 25.05 to 1273.10 kg ha^{-1} and 2.17 to 1.15%, respectively. The highest amount of the available and total potassium were found in Kaul soil, whereas, Balsamand soil with sandy texture showed the lowest amount. No definite trend of different forms of potassium was observed with respect to depth in these soils. Correlation study showed that the different forms of potassium were positively and significantly correlated with organic carbon, silt and clay content of the soils. They were negatively correlated with sand content. The different forms of potassium were positively and significantly correlated among themselves.

Keywords: Soil Physico-chemical properties, distribution of potassium, water soluble–K, exchangeable–K

Introduction

Potassium is a major constituent of the earth crust contained more in igneous rocks than the sedimentary rocks. Potassium comprise on an average of 2.6% of the earth crust, making it the seventh most abundant element and fourth most abundant mineral nutrient in the lithosphere [1]. Among the important K bearing minerals that are found in soil are feldspars and micas as primary and illites and transitional clay as secondary minerals. Soil K-minerals such as feldspars, illites and micas are present in abundant amounts in some soils. The information on vertical distribution of potassium in agricultural soils is important because it indicates the distribution of potassium with respect to depth of soils. It can indicate the depletion as well as accumulation pattern of potassium, if any, within the profile. A five-fold increase in food grain production during the last 35years combined with inadequate and unbalanced nutrient supply has led to a large degree of soil nutrient 'mining' of all the essential plant nutrient in the state of Haryana. In Haryana, farmers generally apply only nitrogen (N), phosphorus (P) and zinc (Zn), as a consequence, deficiencies of potash (K) and other nutrients are spreading in space and time. The intensity of nutrients ($N+P_2O_5+K_2O$) use through fertilizer in Haryana is 167kg/ha consisting of 125.7kg N, 38.7kg P_2O_5 and 2.6kg K_2O with N: P_2O_5: K_2O use ratio of 48.2:14.8:1. The share of potash to total NPK consumption is only 1.55%. The total potash removal by the crops in the state is reported to be 146,000 tonnes against total addition of merely 4,000 tonnes showing a negative non-exchangeable–K, total–K, soil texture, crop rotations and correlation.

Potash balance of 142,000 tonnes and in consequence the potash reserve of the soils of the state has depleted [2]. More than 98% of the total potassium reserve in soils and exists in inorganic combinations which can further be characterized as: water soluble K, exchangeable K, non-exchangeable K and lattice K. Knowledge of different forms of potassium in soil together with their distribution is great relevance in assessing the long-term availability of potassium to crops and in formulating a sound basis of fertilizer recommendation.

Materials and Methods

In the present investigation of distribution of different forms of potassium in soils. All the soil samples varied widely in their physico-chemical properties. The soil samples were collected, air dried ground and passed through 2 mm sieve and analyzed for various chemical properties. Clay content varied from 4.50% in Bhiwani soil to 28.60% in Kaul soil. Kaul soil also exhibited a maximum CEC of 10.23-17.74 cmol (p^+) kg^{-1} followed by 5.10-10.31 and 3.51-5.40 cmol (p^+) kg^{-1} for Bawal and Balsamand soil, respectively.

Table 1: General characteristics soil profile of major physiographic units of Haryana

Profile	Classification	Location	Sand % (2.0-0.02) mm	Silt % (0.02-0.002) mm	Clay % (<0.002) mm	Texture
Koul	Fine loamy, Mixed Hyperthermic calcareous, Typic Haplustepts	KVK Kaul (76^0 39' 41.35"E 29^0 50' 59.60"N)	40.66	30.10	28.60	Clay
Bawal	Coarseloamy, Hyperthermic, Typic Ustorthents	KVK Bawal (76^0 35' 21.40"E 28^0 5' 0.00"N)	75.98	12.19	11.68	Sandy loam
Balsamand	Sandy, Hyperthermic Typic Ustipsamments	Balsamand (75^0 29' 0.00"E 29^0 5' 0.00"N)	92.12	3.38	4.50	Sandy

Table 2: Physico-chemical properties of different soils - A range

	pH (1:2)	EC (dS m^{-1}) (1:2)	CEC [c mole (p+) kg^{-1}]	OC (%)	Texture
Koul	8.10-50	0.23-0.26	10.23-17.74	0.19-0.54	Clay loam
Bawal	7.91-8.13	0.50-1.1	5.10-10.31	0.08-0.14	Sandy loam
Balsamand	8.05-8.27	0.08-0.12	3.51-5.40	0.04-0.08	Sandy

Chemical properties of soils

The chemical characteristics of soil profiles in old alluvial (Typic Haplustepts) aeolian plain (Typic Ustorthents), aeolian plain (Typic Ustipsamments) were determined. The pH of the soil profiles across all the profiles (P1 to P3) varied between 8.10 to 8.12 indicating that the soils were slight alkaline in reaction. The electrical conductivity (EC) of the soil profiles (P1 to P3) varied between 0.12 to 1.10 dSm^{-1}. The organic carbon content of the soil profiles (P1 to P3) varied between 0.08 to 0.54. Soil organic carbon was highest 0.5 per cent in old alluvial (Typic Haplustepts) followed by 0.4 per cent in recent alluvial (Typic Natrustalfs) and lowest 0.08 per cent in aeolian plains (Typic Ustipsamments) in the surface horizon. The cation exchange capacity of the soil profiles (P1 to P3) varied between 4.84 to 17.7. Evidences in support of such observation were also reported by (Ahuja *et al*., 1997) in sand dune toposequences of Haryana.

Table 3: Vertical distribution of different forms of K in different soil profiles of Haryana

Profile (1)	Old alluvial plains (Typic Haplustepts)			
	WS-K	EX-K	NEX-K	Total - K
0-20	24.93	160.25	1273.10	1.91
20-42	19.11	155.54	1511.35	2.10
42-111	14.64	133.21	1504.15	2.17
111-144	11.90	105.54	1482.70	1.96
Range and mean value	11.90-24.93 (17.65)	105.54-160.25 (138.63)	1511.35-1273.10 (1442.82)	1.91-2.17 (2.04)
Profile (P2)	**Aeolian plain (Typic Ustorthents)**			
0-28	9.18	74.57	314.25	1.30
28-64	8.91	71.39	346.7	1.34
64-85	8.12	54.12	357.85	1.35
85-135	7.10	40.18	327.25	1.33
Range and mean value	7.10-9.18 (8.33)	40.18-74.57 (60.07)	314.25-357.85 (336.51)	1.30-1.35 (1.33)
Profile (P3)	**Aeolian plain (Typic Ustipsamments)**			
0-15	8.70	53.45	258.05	1.15
15-30	7.26	52.49	295.25	1.25
30-45	6.86	51.79	304.35	1.27
45-60	6.26	28.09	285.65	1.17
Range and mean value	6.26-8.70 (7.27)	28.09-53.45 (46.46)	25.05-304.35 (285.83)	1.15-1.25 (1.21)

Table 4: Pearson correlation coefficients among different forms of potassium and soil properties

Form-K	WS-K	Ex-K	Non-Ex-K	Total-K	Sand	Silt	Clay	pH	EC	OC	CEC
WS-K	1										
Ex-K	0.94**	1									
Non-Ex-K	0.94**	0.96**	1								
Total-K	0.95**	0.97**	0.99**	1							
Sand	-0.93**	-0.95**	-0.92**	-0.93**	1						
Silt	0.92**	0.93**	0.86**	0.87**	-0.97**	1					
Clay	0.92**	0.95**	0.98**	0.98**	-0.95**	0.89**	1				
pH	-0.94**	-0.88**	-0.85**	-0.86**	0.90**	-0.89**	-0.85**	1			
EC	-0.94**	-0.95**	-0.96**	-0.978**	0.87**	-0.81*	-0.93**	0.88**	1		
OC	0.97**	0.92**	0.96**	0.95**	-0.91**	0.86**	0.94**	-0.95**	-0.96**	1	
CEC	0.97**	0.96**	0.98**	0.98**	-0.97**	0.93**	0.98**	-0.90**	-0.94**	0.96**	1

Distribution of different forms of potassium in soils

The data on the contents of different forms of potassium in each profile of the major physiographic units of Haryana is presented in the Table 3 and the relationship amongst forms of K vis a vis soil properties is presented in Table 4. The insight about K status is crucial in order to develop suitable K nutrient management. Since, there is a continuous but slow transfer of potassium from the primary minerals to exchangeable and slowly available forms, therefore, it is imperative to analyse all the fractions to reveal whether the K is adequate for the sustainable crop production of dominant crops.

Water soluble potassium (WS-K)

Water soluble potassium in the profiles (P1 to P3) ranged from mean values of 17.6, 8.3 and 7.2 mg kg^{-1}, respectively. Higher WSK was observed in old alluvial plains (Typic Haplustepts) and minimum in aeolian plains (Typic Ustipsamments). The WSK was higher in surface horizons and decreased with depth in all the soil profiles. Water soluble potassium was higher in the surface layer and showed a decreasing trend with depth in all the soil profiles (Table 3). It could be attributed to relatively high amount of organic matter in surface layer. This type of behaviour may be due to the fact that organic matter is capable of blocking specific and non-specific K binding sites resulting in reduced amount of K fixation. Therefore, a sufficient amount of K remains in water soluble forms. These results are in agreement with those reported of Singh *et al*. (2001) [11]; Singh (2010) [11]; Butt *et al*. (2017).

Correlation studies revealed that water soluble potassium was significantly correlated with CEC (r=0.97; $p \leq 0.01$), organic carbon (r=0.97; $p \leq 0.01$), silt (r=0.92; $p \leq 0.01$), clay (r=0.92; $p \leq 0.01$) content whereas negatively correlated with pH (r=-0.94; $p \leq 0.01$), sand (r=-0.93; $p \leq 0.01$) and EC(r=-0.94; $p \leq 0.01$). It was interesting to note that the sand fraction was negatively and significantly correlated with all forms of potassium which may be due to low potassium bearing minerals in sand fractions. Water soluble K (Table 5) was positively and highly significantly correlated with exchangeable potassium (r=0.94; $p \leq 0.01$), nonexchangeable potassium (r=0.94; $p \leq 0.01$), and total potassium (r=0.95; $p \leq 0.01$). The strong correlation of this fraction of potassium with other forms indicates that the water soluble potassium was in equilibrium with other forms of potassium. Similar results were also reported by Bhasker *et al*. 2001 and Srinivassarao *et al*. 2002.

Exchangeable potassium (Exch-K)

Exchangeable potassium in the profiles (P1 to P3) ranged from mean value of 138.6, 69.1, 60.0 and 4.4 mg kg^{-1}, respectively. On an average, exchangeable potassium constituted 0.57 per cent of total potassium. Higher Exch-K was observed in old alluvial plains (Typic Haplustepts) and minimum in aeolian plains (Typic Ustipsamments). Exchangeable potassium was higher in the surface layers and decreased with increase in depth in all the soil profiles.

Exchangeable K is held by the negative surface charges on organic matter and clay minerals. It is easily exchanged with other cations and is quite readily available to plants (Havlin *et al*., 2005; Kirkman *et al*. (1994) [6, 7] evinced that exchangeable K is more related to the type of clay and its net negative charge that may be the reason for the variation in exchangeable K in these soils. Exchangeable K also showed a decreasing trend with depth in most of the soil profiles. Annapurna *et al*. (2017) reported that the higher exchangeable K status of surface layer could be due to application of K fertilizers, crop residue, high organic carbon content and higher biological activities.

Correlation studies showed that exchangeable potassium was significantly correlated with CEC (r=0.96; $p \leq 0.01$), organic carbon (r=0.92; $p \leq 0.01$), silt (r=0.93; $p \leq 0.01$), clay (r=0.95; $p \leq 0.01$) content whereas negatively correlated with pH (r=-0.88; $p \leq 0.01$), sand (r=-0.95; $p \leq 0.01$), and EC(r=0.95; $p \leq 0.01$). Exchangeable K (Table 5) was positively and highly significantly correlated with nonexchangeable potassium (r=0.96; $p \leq 0.01$) and total potassium (r=0.97; $p \leq 0.01$). The present findings are in similar line as that of Singh *et al*., 2001 and Gangopadhyay *et al*. 2005 [11]. The better correlation of this forms of potassium with other forms indicate that the different forms of potassium were in dynamic equilibrium with each other.

Non-exchangeable potassium (Non-exch K)

The non-exchangeable potassium in the profiles (P1 to P3) ranged from means values of 1442.8, 336.5 and 285.8 mg kg^{-1}, respectively. On an average, non-exchangeable potassium constituted of 4.38 per cent total potassium. Maximum non-exch K was observed in old alluvial plains (Typic Haplustepts) and minimum in aeolian plains (Typic Ustipsamments). No systematic pattern of depth distribution of non-exchangeable K was observed in these soils. In general, subsurface soils had higher amount of non-exchangeable K compared to surface layers. The difference in pattern of non-exchangeable K in all the physiographic units may be due to the combination of variations in mineralogical composition, particle size distribution, chemical characteristics and weathering process (Rezapour and Samadi, 2012) [9]. These results are in agreement with several researchers Reza *et al*., 2014 [8]. The lower amount in surface layers might be due to the release of fixed potassium to compensate the removal of water soluble and exchangeable potassium by planting and leaching losses. Similar results were reported by Das *et al.* (2000) [3]; Srinivasarao *et al*. (2000) and Gora (2013) [12, 13]. Brar *et al*. (2016) [1] reported that where non-exchangeable K was high in soil showed higher clay and silt content.

Non-exchangeable potassium showed positively significant correlation (Table 5) with CEC (r=0.98; $p \leq 0.01$), organic carbon (r=0.96; $p \leq 0.01$), clay (r=0.98; $p \leq 0.01$) and silt (r=0.86; $p \leq 0.01$) whereas it was negatively correlated with sand (r=-0.92; $p \leq 0.01$) and pH (r=-0.85; $p \leq 0.01$). The relationship of this form with total-K (r=0.99; $p \leq 0.01$) exchangeable-K (r=0.96; $p \leq 0.01$) and water soluble-K (r=0.94; $p \leq 0.01$) was found to be positive and highly significant which showed that equilibrium exist in the soil. The sand fraction was significantly but negatively correlated with all forms of potassium. This may be due to less content of potassium bearing minerals in sand fractions. Das *et al*., 2000 and Chand *et al*., 2000 [2, 3] also observed similar type of correlation in their soils.

Total potassium (Total-K)

Total potassium in the profiles (P1 to P3) ranged from mean values of 2.0, 1.3 and 1.2 per cent, respectively. Highest content of total potassium was found in old alluvial plains (Typic Haplustepts) and lowest in aeolian plains (Typic Ustipsamments). No consistent distribution pattern of total

potassium was observed down the profile in all the physiographic units. In general, subsurface soils had higher amount of total potassium compared to surface layers. Higher total K in soils may be due to the presence of sufficient quantity of potash bearing primary minerals like feldspar and mica and it seemed to be directly related with clay and organic matter content of these soils also. There was no definite trend observed in the vertical distribution of total potassium in the selected soil which might be due to the diversified nature of alluvium deposited. Comparing the total K content among various subsurface to surface soil horizons it was slightly lower in surface though it did not increase regularly with soil depth. This could be due to the effect of potassium depletion by the crops from the surface horizons. Singh *et al*. (2001) [11] while conducting experiment on alluvial soils of Uttar Pradesh also observed higher values of total K in subsurface soils. The results are in agreement with those of Shanwal and Dutta (2001) [10].
The total potassium (Table 5) was significantly and positively correlated with CEC (r=0.98; p=0.01), organic carbon (r=0.95; p=0.01), silt (r=0.87; p=0.01) and clay (r=0.98; p=0.01) content whereas it was negatively correlated with pH (r=-0.86; p=0.01) and sand (r=-0.93; p=0.01). The sequential order of dominance of different forms of K in all the physiographic units was: Total K>NEK>Exch-K>WSK. Similar results were obtained by Yadav *et al*., 1999 [14] in Vertisols of Madhya Pradesh.

Conclusion
The higher WSK was observed in soils having fine texture as compared to coarse textured soils. Water soluble potassium and exchangeable K also showed a decreasing trend with depth in most of the soil profiles. There was no specific trend of non-exchangeable K distribution with respect to soil depth which was very much related to the soil texture as the value increased with the finesses of the texture.

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