Short communication

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Distribution of forms of potassium in Lesser Himalayas of Sikkim, India

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Potassium (K) is an element essential for plant growth and its importance in agriculture is well recognised (Sparks and Huang 1985; Krauss and Johnson 2002). Exchangeable K is widely used to evaluate the soil K status and to predict the crop K requirements (Askegaard and Jørgen 2002). However, other studies (Mutscher 1995) have shown that the exchangeable K alone can not be used as the basis for evaluating K availability under intensive cropping. Research (Kirkman *et al.* 1994; Bansal *et al.* 2002) has shown that there is a continuous but slow transfer of K from the primary minerals to the exchangeable and slowly available forms. Release of K from these non-exchangeable forms of K occurs when the levels of exchangeable K and solution K (labile K) are decreased by crop removal and/or leaching (Sparks *et al.* 1980). The soil K is typically divided into four forms: water soluble K, exchangeable K, non-exchangeable K and lattice K (Sparks 1987).

The distribution of K forms differs with agrocological regions and the depth of soils in North-eastern India depending on management practices (Reza *et al.* 2014). In the Western Himalayas both exchangeable and non-exchangeable K are variable (low to high) (Subba Rao *et al.* 2011). The soils of Lesser Himalayas are rich in potassium reserve in primary and secondary clay minerals (Talib and Verma 1990). But the challenge of K management are far greater in the Himalayan region because of the contradictory properties arising from the dominance of K-bearing minerals on one hand, and low to medium K availability (exchangeable + water soluble K) status on the other. Information is therefore, necessary on the different forms of K in these soils. Based on these facts, the objective of this study was to investigate the different forms of K and their interrelationship in Dzongu Farm soils of North Sikkim district, Sikkim.

The study area was the research farm of ICAR Research Complex for NEH, Tadong, Sikkim namely Dzongu of North Sikkim district, Sikkim. The area falls under the lesser Himalayan region. The general slope of the farm ranges between 3-30 per cent. The soils of the farm area have developed from the young Siwalik formations of sedimentary rocks belonging to gneissic with less mica. The area receives about 3000-3500 mm of mean annual rainfall. Three landforms in the farm, moderately steep sloping (15-30% slope), moderately sloping (8-15% slope) and gently sloping (3-8% slope) were chosen for profile excavation. The profiles were studied, sampled and classified following the procedure outlined by Soil Survey Staff (1993). Selected physical and chemical characteristics of the profiles are presented in Table 1. The soil samples were analysed for their particle-size distribution by international pipette method. A combined glass calomel electrode was used to determine the pH of aqueous suspension (1:2 soil:solution ratio). Organic carbon was determined by Walkley and Black (1934) method. Exchangeable acidity was determined after extracting the soil with 1 N KCl solution, followed by titration with 0.1 N NaOH solution. Cation exchange capacity (CEC) was determined by saturating soil with 1 N NH_4OAc at pH 7 and subsequently subjecting it to the semi-micro distillation. Exchangeable K (K_{ex}) was determined by leaching soil samples with 1N NH4OAc and analysing the extract. Reserve K (K_{res}) was extracted from the residue of 1N NH_4OAc extract with 1N HCl using a soil:acid ratio of 1:10 and boiling the suspension for 1 hrs (Piper 1950; Haylock 1956). Total K (K_t) was obtained by digesting the soils in a mixture of concentrated HNO_3 and concentrated $HClO_4$ using soil:acid ratio of

1:10. The residual K (K_{du}) represents the difference between K_t and the sum of K_{ex} and K_{res}. Analysis of variance was performed using SPSS 15.0 (SPSS Inc.) to test the significance of variations in the distribution of K forms and soil properties. Relationships between various soil properties and spatial distribution of K were established by using general linear model.

The clay fraction was much lower compared to sand and silt fractions in the profiles for all the landform positions (Table 1). The clay content ranged from 5-20% and from 0.6-2.9% for organic carbon content. Soil pH values are almost 5 and less due to leaching of bases by high rainfall. The highest pH value was found in gently sloping as compared to moderately sloping and moderately steep sloping profiles which may be ascribed due to leaching of more bases from upper and middle slopes. Exchangeable H^+ and Al^{3+} ranged from 0.12-0.91 and 0.01-0.70 cmol(p^+)kg^{-1}, respectively in all the three topographic positions. They also varied with depth of the profile. The CEC of soils varied from 4.3-9.2 cmol(p^+)kg^{-1} in all the soil profiles. Exchangeable K (K_{ex}) is the immediate source of K supply to plant. The K_{ex} in soil ranged from 0.10–0.22 cmol(p^+)kg^{-1} (Table 2) having irregular distribution with depth. The mean value of K_{ex} was 0.15 cmol(p^+) kg^{-1}, constituting 0.49-0.67% of the total K. Sharma *et al.* (2006) and Pasricha (2002) also made similar observations for Siwalik soils of Punjab. Considering 157 kg ha^{-1} of K_{ex} as the lower limit of sufficiency (Bray 1948), it was adequate barring Ap horizon of all the pedons. The values of K_{res} were lower than the values of total K (K_t) and residual K (K_{du}) in the different horizons of pedons with irregular distribution with depth. The K_{res} values ranged from 6.6–11.8 cmol(p^+)kg^{-1} soil (Table 2) in different horizons of the pedons. The mean value of K_{res} was 8.8 cmol(p^+)kg^{-1}, which was 29.1-38.4% of the total K. K_{res} constitutes a major part of the total non-exchangeable K which is released under intensive cropping. The K_{du} ranged from 11.7-29.0 cmol(p^+)kg^{-1} (Table 2) in the different horizons of pedons. The mean value of K_{res} was 17.5 cmol(p^+)kg^{-1}, which was 61.0-70.4% of the total K. A large presence of K_{du} could be because the soils are rich in K-bearing minerals like micas, illites and other K minerals (Sidhu 1982; Sharma *et al.* 2006). K_t ranged 21.7-38.4 cmol(p^+)kg^{-1} in surface soil and 19.2–34.5 cmol (p^+)kg^{-1} in subsurface soil (Table 1). It ranged from 19.2-38.4 cmol(p^+)kg^{-1} in soils of different horizons of pedons (Table 2) and with mean value was 26.5 cmol(p^+)kg^{-1}.

Table 1. Some physical and chemical properties of soils of Dzongu farm

Horizon	Depth (cm)	Sand	Silt	Clay	O.C	pH (H_2O)	H^+	Al^{3+}	CEC
		%					cmol(p^+)kg^{-1}		
Pedon−1 (Moderately steep sloping, 15−30% slope)									
Ap	0–15	69.4	20.6	10.0	1.9	4.7	0.64	0.01	5.7
Bt1	15–36	72.2	12.8	15.0	1.6	4.8	0.91	0.21	6.9
Bt2	36–60	67.0	18.0	15.0	2.2	4.8	0.12	0.28	7.2
Pedon−2 (Moderately sloping, 8−15% slope)									
Ap	0–16	66.8	13.2	20.0	2.4	4.8	0.98	0.14	9.2
Bw1	16–54	65.5	17.0	17.5	2.9	4.8	0.87	0.49	8.1
Bw2	54–83	85.6	9.4	5.0	0.6	4.9	0.48	0.01	4.3
Pedon−3 (Gently sloping, 3−8% slope)									
Ap	0–22	72.0	18.0	10.0	2.0	4.8	0.91	0.21	5.2
Bw	22–63	68.6	26.4	5.0	2.0	5.0	0.71	0.49	4.3
Bt1	63–97	64.2	20.8	15.0	1.2	5.1	0.72	0.70	7.1
Bt2	97–108	65.8	16.2	18.0	1.6	5.0	0.65	0.63	8.3

Table 2. Distribution of different forms of potassium in soils of Dzongu farm

Horizon	Depth (cm)	Exch. K	Reserve K	Residual K	Total K
		cmol(p^+)kg^{-1}			
Pedon–1					
Ap	0–15	0.22	6.6	14.9	21.7
Bt1	15–36	0.10	7.4	11.7	19.2
Bt2	36–60	0.15	8.2	17.2	25.6
Pedon–2					
Ap	0–16	0.20	9.2	29.0	38.4
Bw1	16–54	0.13	9.0	19.1	28.1
Bw2	54–83	0.06	11.8	22.7	34.5
Pedon–3					
Ap	0–22	0.18	7.7	15.2	23.0
Bw	22–63	0.13	11.0	14.5	25.6
Bt1	63–97	0.13	8.4	15.7	24.3
Bt2	97–108	0.18	9.5	17.2	26.9

Correlation analysis suggested that (Table 3), K_t was significantly and negatively correlated with sand (–0.458*). This is because of the presence of quartz, which makes up half of the sand fraction and does not retain K. The positive correlations of K_t with silt and clay indicated that K bearing minerals are present in terms of feldspars, mica, illite and vermiculites (Deka *et al.* 1995). K_{ex} was significantly and positively correlated with organic carbon (0.510*) but significantly and negatively correlated with sand (–0.578*). The positive correlations amongst the forms of K (Table 4) indicated the interdependence and dynamic equilibrium between K forms. K_t was significantly and positively correlated with K_{res} (0.638*) and K_{du} (0.970*). K_{ex} had no significant relationship with all other forms of K. This may be due to leaching and/or uptake of this form of K by plant owing to its high mobility.

There was a strong association between K forms and landforms, which suggest that in the study area, K-management must be based on the study of landforms.

Table 3. Correlation between the different forms of potassium and soil properties of Dzongu farm

	Exch. K	Reserve K	Residual K	Total K
Sand	–0.578*	0.438	0.141	–0.458*
Silt	0.337	–0.140	0.497*	0.232
Clay	0.370	–0.385	0.286	0.144
pH	–0.342	0.513	–0.103	0.055
O.C	0.510*	–0.329	0.112	0.006
H^+	0.179	–0.158	0.082	–0.194
Al^{3+}	–0.054	0.128	–0.272	–0.194
CEC	0.366	–0.255	–0.192	0.226

*Significant at the 0.05 level

Table 4. Correlation between the different forms of potassium in the soils of Dzongu farm

	Exchangeable K	Reserve K	Residual K	Total K
Exchangeable K	1.00			
Reserve K	–0.554	1.00		
Residual K	0.096	0.434	1.00	
Total K	0.061	0.638*	0.970**	1.00

*Significant at the 0.05 level, **Significant at the 0.01 level

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