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Distribution of potassium and clay minerals assemblage in some paddy soils of Lesser Himalayas

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Abstract : Different forms of potassium were studied in ten representative soils of different physiography in lesser Himalayas. The amount of total potassium ranged from 12320.1 to 18154.5 mg kg^{-1} with a mean value of 15412.8 mg kg^{-1}. The water soluble, exchangeable and non-exchangeable potassium ranged from 4.7 to 14.8, 49.9 to 154.8 and 551.9 to 917.7 mg kg^{-1}, (mean value of 7.2, 71.8 and 680.9 mg kg^{-1}) respectively. The water soluble and exchangeable potassium were higher in the soils of high altitude than in mid and low altitude soils. The non-exchangeable potassium constituted on an average (4.41%) of total potassium and more than 95 % of the total potassium was in the mineral form. The distribution of potassium in soil separates was dependent not only on potassium concentration of the fraction but also on the quantity of these separates in the soil. Out of ten samples, nine came under low exchangeable and non-exchangeable potassium category and only one sample came under high exchangeable and low non-exchangeable category. X-ray diffraction analysis showed that there was a disintegration and transformation of illite to other clay minerals. All soils had illite in higher amounts than other minerals. Due to high reserves of potassium rich minerals like illite in alluvial soils, significant negative correlation was found between illite and water soluble, available and exchangeable potassium owing to their low concentration in soils.

Additional key words: *Correlation, clay mineralogy, soil fractions, potassium*

Introduction

In soils, potassium exists in different forms *viz.* water soluble, exchangeable, non-exchangeable and lattice potassium. The water soluble and exchangeable together constitutes the plant available potassium (Mishra *et al.* 1993). The different forms of soil potassium are in dynamic equilibrium and any depletion in a given potassium form is likely to shift equilibrium in the direction to replenish it (Ramamoorthy and Paliwal 1976). Singh *et al.* (1993) reported high correlations among different forms of potassium in some Indian soils.

Potassium, a component of several minerals, is released to soluble and exchangeable forms by weathering of the minerals (Huang 1977). Although the relationship between different forms of potassium and release characteristic as a function of soil mineralogy are well established, yet information available is meager (Bhonsle *et al.* 1992). Total soil potassium reserves are generally large, although the distribution of potassium forms differs from soil to soil, as a function of dominant soil minerals present. Information on various forms of potassium and clay mineralogy is helpful in understanding the rate of release of potassium from soils.

The intensive cropping practiced over the last 30 years, coupled with lack of information on the present status of potassium in the soils of lesser Himalayas and their relationship with clay mineralogy, was the reason for the present investigation.

Materials and Methods

Ten surface soil samples from paddy fields (cultivated) of different locations, representing three different zones *viz.* High altitude zone, Mid altitude zone (Kerewa) and Low altitude zone (Valley basin) of lesser Himalayas were collected. The samples were air-dried in shade and processed to pass 2mm sieve for laboratory analysis.

The soil samples were analyzed for total, non-exchangeable, exchangeable and water soluble potassium contents. The water soluble potassium was determined in a saturation paste extract. NH_4OAc extractable potassium was determined as per the procedure outlined by Pratt (1982). Fixed potassium was determined by extracting the soil with 1*N* boiling HNO_3 according the method outlined by Pratt (1982). To get non-exchangeable potassium values, the 1*N* NH_4OAc extractable potassium values were deducted from the potassium values obtained in the extract of soil with boiling 1*N* HNO_3. The determination of total potassium was made in the extract obtained by the digestion of soil samples with hydrofloric and perchloric acids as outlined by Pratt (1982). Lattice potassium was calculated by the difference between total potassium and 1*N* HNO_3 extractable potassium. The determination of potassium in the extract was made on a flame photometer. pH and EC were determined in saturation paste and CEC by saturating soil with NaOAc as outlined by Rhoades (1982). Walkley and Black method was followed for organic carbon determination. The mechanical analysis was carried by International Pipette Method.

The principal clay minerals in these soils were estimated from X-ray diffraction data using a Phillip X-ray Diffractometer with Cu K_α radiation. The clay samples were divided into two fractions which were saturated with Mg and K by treating with 1*N* $MgCl_2$ and 1*N* KCl. These clays were made salt free by repeatedly washing with distilled water. Parallel oriented clay specimens were prepared on glass slides and air-dried at room temperature. The magnesium saturated samples were solvated with ethylene glycol and then scanned. Potassium saturated samples were scanned after air drying at room temperature and also after heating at 550°C for 1 hour.

Results and Discussion

The important soil properties are presented in table 1. The data on distribution and forms of potassium in these soils are presented in table 2. The available potassium ranged from 46.8 to 169.7 mg kg^{-1} with a mean value of 79.2 mg kg^{-1}. The per cent contribution towards total potassium ranged from 0.38 to 0.94 per cent, with a mean value of 0.51 per cent. The highest and lowest values were recorded in the soils of high altitude zone and mid altitude zone, respectively (Table 2). Considering 49.01mg kg^{-1} available soil potassium as general initial limit for crops (Murthy and Hirekerur 1980), soil sample from Telbal (S_{10}) is low and Kunzer (S_6), Dialgam (S_7) and Kreeri (S_5) soils are near to critical limit. The water soluble potassium ranged from 4.7 to 14.8 mg kg^{-1} with a mean value of 7.2 mg kg^{-1}(Table 2). The contribution of water soluble potassium towards total potassium ranged from 0.03 to 0.08 per cent, with a mean value of 0.05 per cent. Comparing the means, all the soils have less than 7.2 mg kg^{-1} water soluble potassium except S_1, S_2 and S_3 soils with 14.8, 10.1 and 10.9 mg kg^{-1}, respectively. The soils of high altitude zone have higher content of water soluble potassium as compared to other zones.

The exchangeable potassium varied from 49.9 to 154.8 mg kg^{-1} with a mean value of 71.8 mg kg^{-1}(Table 2). The distribution pattern of exchangeable potassium in different altitude zones was similar to that of available potassium. The contribution of exchangeable potassium towards total potassium ranged from 0.37 to 0.86 per cent, with a mean value of 0.47 per cent. The content of non-exchangeable potassium varied from 551.9 to 917.7 mg kg^{-1} with a mean value of 680.9 mg kg^{-1}(Table 2). The

Table 1. Physical and chemical characteristics of soils

Parameter	High altitude	Kerewa	Valley basin
Sand (%)	18.4 – 19.3 (18.9)	18.5 – 24.5 (20.9)	18.5 – 38.8 (25.1)
Silt (%)	40.5 – 44.4 (42.3)	41.9 – 49.0 (44.6)	39.3 – 55.6 (48.2)
Clay (%)	29.8 – 39.0 (35.3)	16.0 – 36.0 (29.1)	19.0 – 23.2 (21.3)
Texture	clay loam	clay loam	silt loam
pH (1:2.5)	6.0 - 6.8 (6.2)	6.3 - 6.7 (6.4)	6.7 - 8.0 (7.5)
EC (dsm^{-1})	0.04 – 0.06 (0.04)	0.04 – 0.07 (0.05)	0.11 – 0.13 (0.12)
O.C. ($g\ kg^{-1}$)	13.5 – 26.7 (20.2)	11.1 – 18.3 (13.7)	15.6 – 21.3 (18.2)
Free $CaCO_3$ ($g\ kg^{-1}$)	8.5 – 11.0 (10.0)	9.8 – 12.0 (10.5)	7.5 –9.5 (8.3)
CEC $cmol(p^+)\ kg^{-1}$	17.9 – 22.4 (19.5)	13.8 – 22.9 (17.9)	13.9 – 17.9 (16.1)
1NNH_4 OAc-K ($mg\ kg^{-1}$)	69.8 – 169.7 (113.1)	55.0 –69.8 (61.6)	46.8 – 89.7 (66.7)

* *Figures in parentheses indicate mean of different parameters*

lowest and highest non-exchangeable potassium values were observed in the soils samples from mid altitude zone and high altitude zone, respectively. Higher content in high altitude zone soils is attributed to higher content of clay and organic matter. The per cent contribution towards total potassium ranged from 4.48 to 5.05 per cent, with a mean value of 4.42 per cent. It seems that with cropping over many years, the non-exchangeable potassium is being depleted in these soils.

The lattice potassium ranged from 11770.2 to 17284.8 mg kg^{-1} with a mean value of 14730.3 mg kg^{-1}. The per cent contribution towards total potassium ranged from 95.5 to 95.7 per cent, with a mean value of 95.6 per cent (Table 2). The lattice potassium represents the largest portion (more than 95 %) of soil potassium, which suggested that parent material was the origin of most of the potassium. Total potassium concentration in soils of different zones ranged from 12320.1 to 18154.5 mg kg^{-1}. Similar but higher values of total potassium in these soils have been attributed to the presence of potassium rich minerals like illite (Gupta *et al.* 1986). Ahmad and Walia (1999) reported that the contribution of water soluble, available, exchangeable, non-exchangeable and lattice potassium towards total potassium was 0.05, 0.51, 0.47, 4.42 and 95.6 %, respectively. Similar results were also reported by Kaskar *et al.* (2001).

Tentative grouping of ten soil samples into categories of potassium availability integrating exchangeable and non-exchangeable potassium was done according to the procedure suggested by Tandon and Sekhon (1988). There were two situations *ie* low-low, and high-low, exchangeable and non-exchangeable

Table 2. Distribution of different forms of potassium (mg kg^{-1}) in soils

Physiographic zone	Sites	Location	Total-K	Water soluble-K	Available-K	Exchangeable-K	Non-exchangeable-K	Lattice-K
High altitude zone	S_1	Badripora	18053.1	14.8 (0.08)*	169.7 (0.94)	154.8 (0.86)	767.9 (4.25)	17284.8 (95.7)
	S_2	Kangan	18154. 5	10.1 (0.06)	99.8 (0.55)	89.7 (0.49)	917.7 (5.05)	17238.0 (95.0)
	S_3	Tangmerg	17854.2	10.9 (0.06)	69.8 (0.39)	59.7 (0. 33)	767.9 (4.30)	17085.9 (95.7)
Mid altitude zone	S_4	Tral	14710.8	5.2 (0.04)	69.8 (0.47)	65.1 (0.44)	628.3 (4.27)	14082.9 (95.7)
	S_5	Kreeri	14063.4	4.7 (0.03)	59.7 (0.42)	54.6 (0.39)	598.7 (4.26)	13466.7 (95.8)
	S_6	Kunzer	12569.7	5.1 (0.04)	55.0 (0.44)	49.9 (0.37)	583.4 (4.64)	11984.7 (95.3)
Low altitude zone	S_7	Dialgam	14742.0	5.4 (0.04)	59.7 (0.40)	54.6 (0.40)	618.5 (4.20)	14121.9 (95.8)
	S_8	Ganasthan	15510.3	4.7 (0.03)	69.8 (0. 45)	64.7 (0.42)	648.2 (4.18)	14862.9 (95.8)
	S_9	Mazhama	16130.4	5.1 (0.03)	89.7 (0.56)	84.6 (0.52)	728.1 (4.51)	15401.1 (95.5)
	S_{10}	Telbal	12320.1	5.5 (0.04)	46.8 (0.38)	71.7 (0.34)	551.9 (4.48)	11770.2 (95.5)
Mean			15412.8	7.2 (0.05)	79.2 (0.51)	71.8 (0.47)	680.9 (4.42)	14730.3 (95.6)
Range			12320.1 – 18154. 5	4.7 - 14.8	46.8 - 169.7	54.6 - 154.8	551.9 - 917.7	11770.2-17284.8

* *Figures in parentheses indicate potassium fractions in per cent total potassium*

Table 3. Tentative grouping of soil samples

Situation	Exchangeable -K	Non-exchangeable - K	Expected need for K - application	Sampling (sites)	No. of samples in each category
A.	Low	Low	Will readily respond to potassium application.	Kangan Tangmerg Tral Kreeri Kunzer Dialgam Ganasthan Mazhama Telbal	9
B.	High	High	Can support crops for sometime but may soon get depleted.	Badripora	1

Note: Exchangeable K, less than 100 mg kg^{-1} is low, more than 100 mg kg^{-1} is high;
Non-exchangeable : less than 1000 mg kg^{-1} is low, more than 1000 mg kg^{-1} is high

potassium, respectively. It was observed that out of ten soil samples, nine came under low exchangeable potassium and low non-exchangeable potassium category (Table 3). Only one sample came under high exchangeable potassium and low non-exchangeable category. These chemical analyses are indicative of the low potassium supplying power of these soils. However, field trials would lead more credence to these observations.

Average total potassium concentration ranged from 14235 to 15678 mg kg^{-1} in sand, 13845 to 16692 mg kg^{-1} in silt and 15054 to 17472 mg kg^{-1} in clay in different zones of the valley (Table 4). On an average, total potassium concentration in sand, silt and clay fractions was in the ratio of 1.0:1.1:1.3. Benipal *et al.* (2001) reported that total potassium concentration in sand, silt and clay fractions was in the ratio of 1.0:1.1:1.4, while Sharma (1981) reported the ratio of 1.0:1.6:2.3. As far as contribution of different soil fractions to total potassium was concerned, on an average sand contributed 31.9 to 33.0%, silt 32.1 to 35.5 % and clay 32.0 to 34.9%. The contribution of silt fraction with respect to total potassium was the highest. This could be explained on the basis of higher silt content of these soils. Dhillon and Dhillon (1994) indicated that per cent contribution of coarse fraction towards total potassium concentration was higher in alluvial soils. The average fixed potassium concentration ranged from to 702 to 936 mg kg^{-1} in sand, 624 to 1014 mg kg^{-1} in silt and 1599 to 1755 mg kg^{-1} in clay in different zones of the valley. On an average per cent contribution of sand to fixed potassium ranged between 23.1 to 25.3 %, the silt contributed 20.5 to 27.4 % and contribution from clay fraction was 47.3 to 56.6 %. A perusal of the data (Table 4) indicated that silt fraction contributed the highest to the total potassium followed by clay and sand, whereas in fixed potassium contribution of clay fraction was maximum and sand and silt fractions contributed almost equally. Highest potassium concentration in coarse fraction is attributed to the presence of biotite, muscovite and feldspar (Bhangu and Sidhu 1993). On the other hand, higher concentration of fixed potassium in clay fraction of these soils was attributed to the presence of illite (Bhangu and Sidhu 1993).

Table 4. Total and fixed potassium concentration (mg kg^{-1})

Soil fraction	Total potassium (mg kg^{-1})			Fixed potassium (mg kg^{-1})		
	High altitude	Kerewa	Valley Basin	High altitude	Kerewa	Valley Basin
Sand	15678 (31.9)*	14235 (33.0)	15366 (32.5)	936 (25.3)	780 (25.3)	702 (23.1)
Silt	16692 (33.5)	13845 (32.1)	16185 (35.5)	1014 (27.4)	702 (22.8)	624 (20.5)
Clay	17472 (34.6)	15054 (34.9)	16068 (32.0)	1755 (47.3)	1599 (51.9)	1716 (56.6)

* *Figures in parentheses indicate percent contribution of soil fractions to total potassium*

Table 5. Relative proportion of different clay minerals in soils

Clay minerals	High altitude	Kerewa	Valley basin
Chlorite	6.0-7.0 (6)	5.0-6.0 (5)	6.0-7.0 (6)
Smectite	6.0-7.0 (7)	4.0-6.0 (5)	5.0-7.0 (6)
Hydroxy interlayered vermiculite	5.0-7.0 (6)	6.0-7.0 (7)	7.0-8.0 (8)
Illite	57.0-60.0 (58)	61.0-62.0 (62)	57.0-61.0 (60)
Kaolinite	7.0-8.0 (7)	6.0-7.0 (6)	5.0-8.0 (6)
Mixed layer	13.0-14.0 (14)	12.0-13.0 (13)	11.0-12.0 (12)

* *Figures in parentheses indicate mean value of relative proportion of clay minerals*

The mineralogy of the Kashmir valley, irrespective of the percentage, is dominated by illite with small amounts of mixed minerals, hydroxy-interlayered vermiculite, chlorite, smectite and kaolinite (Table 5). This has been confirmed by the occurrence of strong sharp peak at 10.0 to 10.5 A^0 in magnesium saturated samples with higher order peak at about 5.0 A^0. The glycolated samples showed the basal reflection of 10.0 A^0 to 10.4 A^0. Upon heating, the peak did not expand but the reflection became more intense, indicating the presence of illite. The 10 A^0 reflections showed asymmetrical broadening towards 2θ angle, suggesting the presence of degraded nature of illite in these samples. The diffraction spacing of approximately 14.0 A^0 obtained from magnesium saturation, may be contributed by smectite, hydroxy-interlayered vermiculite or chlorite or by mixture of these species. On glycolation, a portion of 14.0 A^0 expanded to 17.0 A^0, indicating thereby the presence of smectite. Among 14.0 A^0 minerals, chlorite was one of the components because of persistence of some portion of 14.0 A^0 reflection after heating potassium saturated clays at 550^{0}C. The minerals of kaolinite group are

Table 6. Relationship (r) of different forms of potassium with clay mineralogy

Forms of potassium	Semi quantitative estimate of clay minerals					
	Chlorite	Smectite	Hydroxy interlayered vermiculite	Illite	Kaolinite	Mixed layer
Water soluble-K	0.245	0.453	-0.558	-0.591	0.534	0.760*
Available-K	0.210	0.541	-0.355	-0.766**	0.601	0.592
Exchangeable-K	0.203	0.541	-0.328	-0.772**	0.597	0.564
Non-exchangeable-K	0.524	0.557	-0.397	-0.724*	0.460	0.575
Lattice-K	0.493	0.797**	-0.559	-0.745*	0.435	0.670*
Total-K	0.496	0.788**	-0.561	-0.747*	0.438	0.669*

characterized by strong reflection at 7.2 A^0 and 3.6 A^0, which disappears and decreases in intensity on thermal treatment. Similar findings have also been reported by Gupta *et al.* (1988).

The relationships of different potassium forms with minerals present in the clay fractions are presented in table 6. Illite had significant and negative correlation with available and exchangeable potassium pool of soils. The alluvial soils had high reserves of potassium due to presence of potassium rich minerals such as illite (Sidhu and Gilkes 1977), but the concentration of potassium in available and exchangeable forms was low, which may be the possible reason for such a relationship. Kaolinite showed non-significant correlation with available and water soluble potassium form, because kaolinite had lower adsorption than other minerals (Sharpley 1989). Relationship of different potassium forms with smectite, hydroxy-interlayered vermiculite and chlorite was also non-significant.

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