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Potassium bearing minerals in some soils of semi-arid (Haryana) and humid (Assam) regions of India

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Abstract: Mineralogical analysis was carried out in fourteen typifying pedons of semi-arid and humid regions of India to identify the potassium bearing minerals in different particle-size fractions. Muscovite, biotite and K-feldspars were the prime K-bearing minerals present in the sand and silt fractions of these soils. Sand fractions of aeolian plain and rugged hilly terrain of semi-arid region of Haryana as well as humid region of Assam had higher amount of feldspars than micaceous minerals and a reverse trend was observed in Yamuna alluvial plain of Haryana. Orthoclase feldspar dominated the coarse fraction of Yamuna alluvial plain. Silt fraction of this zone had relatively higher mica than aeolian plain and rugged hilly terrain compared to their sand fraction. Micas were predominantly dioctahedral, particularly in humid region. Coarse fraction of Entisols of humid region had higher amount of feldspars and micas followed by Inceptisols of North Bank Plain zone. Illite was the prime K-bearing mineral in clay fraction and the content of this mineral was higher in semi-arid region soils.

Additional key words: *K bearing minerals, Yamuna alluvial plain, Brahmaputra valley, X-ray diffractogram*

Introduction

The availability of K in soil depends upon the kind of K-bearing minerals, their degree of weathering as well as the intensity of soil forming processes. Potassium bearing minerals in soil generally belong either to the framework silicates (K-feldspars and leucite) or layer silicates such as muscovite, phlogopite, biotite and illite (Wilson 1992). Approximately 98% of the soil K is bound in these minerals whereas only 2% is in solution and exchangeable form which are considered as the most available form of K for plant. However, it has been reported that the very large reserve of non- exchangeable and mineral K might become available over a period of time in response to plant K removal and meet the excess K requirement (Krishnakumari *et al.*1984; Dutta and Shanwal 2006). Thus, information about the nature and relative abundance of K bearing minerals in soil is of much relevance in assessing K supplying power of a soil. Several studies has been made on mineralogical aspect of alluvial soils of India. However in most of the works, emphasis laid on pedogenic aspect of mineral assemblage, more particularly in the mineralogy of clay fraction. With this view, the present investigation was initiated to study the distribution of K bearing minerals in some intensively cultivated alluvial soils of semiarid and humid region of India.

Materials and Methods

The vast alluvial plain of India extends from the Indo-Gangatic Plain of Punjab in the north to the narrow Brahmaputra Valley of Assam in the north east. In the present study, two distinct parts of this alluvial plain have been undertaken, one from the semi-arid and the other from the humid region. Out of the fourteen locations selected for this study, ten (P1 to P10) were taken from the different agro-ecological sub-zones of Haryana (semi-arid) and four (P11 to P14) were from two agro-climatic zones of Assam (humid). The P1 and P2 from aeolian plain and P3 and P4 from rugged hilly terrain. Soil profiles were exposed and horizon-wise samples were collected. Samples were dried, ground to pass 2 mm sieve. The different particle-size groups were quantitatively separated by gravity sedimentation technique (Jackson 1986). Organic carbon was determined by Walkly and Black's (1934) wet digestion method. Soils were classified as per Soil Taxonomy (Soil Survey Staff 1998). Sand and silt were separately ground and random powder X- ray diffractograms were obtained. Sand obtained from dry sieving using 80-mesh sieve (< 0.5mm) was cleaned with 6 *N* HCl and $SnCl_2$ solution and grains were separated into light and heavy minerals using tetrabromoethane. The light sand fraction were then washed, dried and mounted on glass slide using Canada balsam and studied under polarizing microscope. X-ray diffraction pattern of clay fraction was obtained from basally oriented specimens for five different treatments (Mg air dried, Mg glycerol solvated, K air dried, K-300°C and K-550°C) using a Philips X-ray diffractometer with Ni filtered Cu-Kα radiation. Semi-quantitative estimation was carried out on the basis of relative peak area ratio after necessary background correction following the procedure of Gjems (1967).

Results and Discussion

The weighted mean of particle-size distribution and organic carbon content of the pedons are presented in (Table 1). Soils varied in their sand (22.1 – 84.4%), silt (5.9 – 55.8%) and clay (8.8 – 35.6%) contents. Organic carbon content was higher in humid region (0.46 –0.80%) than semi-arid soils (0.13 – 0.48%) which might be attributed to dense weed canopy and a slow decomposition rate.

Potassium bearing minerals in sand fraction

Micas and K-feldspars were the major K bearing minerals in sand fraction of these soils (Table 2). Quartz dominated the overall mineral composition (46 – 75%) of all the pedons. The distribution of micas and feldspars exhibited distinct variation between the regions and within the soils of same region. The mineralogical sequence in pedons (P5 – P10) was quartz > micas> feldspars > chlorite and it was quartz > feldspars > micas in P1 to P4. Pedons (P5 to P10) had 25% micas (weighted mean) followed by soils of aeolian plain (21%). Mica was low (10%) in P3 and P4 as supported by weak to moderate intensity reflection at 10 and 5 Å positions. The low content of micas in these soils was related

Table 1. Weighted mean of particle size distribution and organic carbon

Pedon	Location	Classification	Horizon (demarcation depth)	Sand	Silt	Clay	OC
				%			
P1	Chautala	Aridic Haplustept	0:8:16:46:95:140	66.0	22.2	11.8	0.28
P2	Bhiwani	Fluventic Haplustept	0:22:55:79:119:160	25.9	42.7	31.4	0.38
P3	Satnali	Typic Ustipsamment	0:11:25:57:75:170	84.4	5.9	9.7	0.40
P4	Narnaul	Typic Ustorthent	0:12:33:62:130	81.3	8.6	10.1	0.22
P5	Bhodsi	Fluventic Haplustept	0:19:60:91:120	46.9	26.8	26.3	0.39
P6	Palwal	Typic Haplustept	0:25:57:110	31.9	38.7	29.4	0.42
P7	Sonepat	Typic Ustifluvent	0:15:62:90:130	83.3	7.9	8.8	0.22
P8	Karnal	Typic Natrustalf	0:15:48:85:145:170	51.9	24.1	24.0	0.24
P9	Pipli	Typic Haplustept	0:15:25:45:80:110	22.1	42.6	35.3	0.27
P10	Ambala	Typic Haplustept	0:15:37:70:88:120	27.7	43.4	28.9	0.13
P11	Jorhat	Oxaquic Dystrochrept	0:20:58:115:170	37.1	27.3	35.6	0.46
P12	Kokila	Typic Fluvaquent	0:5:12:22:47:80	34.5	55.8	9.7	0.80
P13	Biswanath	Fluventic Dystrochrept	0:11:23:64:130	47.3	23.0	29.7	0.52
P14	Chatia	Fluventic Dystrochrept	0:10:32:73:112:160	48.9	21.8	29.3	0.54

Table 2. Relative abundance of minerals in sand and silt fraction of the soils (weighted mean of the soil profile, in per cent)

Pedon	Sand				Silt					
	Q	F	M	CH	Q	F	M	CH	K	ISM
P1	49	30	21	-	39	24	31	2	3	-
P2	51	28	21	-	43	27	24	3	3	1
P3	70	21	10	-	48	25	24	2	2	1
P4	72	18	10	-	46	25	22	4	4	1
P5	52	21	24	3	36	19	34	6	6	-
P6	46	21	28	5	30	24	39	4	4	-
P7	47	24	27	2	33	20	42	3	3	-
P8	54	20	23	2	37	22	35	2	4	-
P9	61	14	22	2	43	17	37	2	1	-
P10	58	16	24	2	41	21	33	3	2	-
P11	75	12	8	5	67	15	10	4	5	1
P12	55	28	16	2	49	25	21	1	3	-
P13	61	21	16	2	54	26	12	4	4	-
P14	61	21	16	2	56	19	19	4	3	-

to its original parent rock, *i.e.* sandstone, rhyolite and granite. The micas in pedons (P1 to P4) appeared to be mostly dioctahedral as indicated by fairly moderate intensity peak at 5 Å. Presence of biotite was also recorded in these soils. The observations are in conformity with the findings of Chaudhary *et al.* (1989). Mica flakes (mostly muscovite) in pedons (P5 to P10) was colourless, thin shaped and belong to $2M_1$ polymorph that suggested their formation under high temperature and pressure environment. Biotite flakes of these soils, constituting a small portion of micas, were light brown to reddish brown in colour. A small amount of chlorite (2-5%) was also detected by its specific peak at 14.2 and 7.02 Å. The presence of chlorite as an alteration product of micas in these soils corroborated the observation of Kapoor *et al.* (1981). Sand fraction of P1 and P4 had fairly high amount of feldspar (28-30%) as indicated by weak to strong reflections at 6.13, 4.02, 3.47, 3.23 and 3.17 Å positions. The strong reflections at 3.17 and 4.02 Å showed the dominance of plagioclase over K-feldspars. The X-ray diffraction of sand fraction in P3 and P4 also exhibited similar kind of peaks, confirming the presence of higher amount of plagioclase feldspar. Microscopic studies showed little alteration of these minerals. A different trend was observed in the sand fraction of Yamuna alluvial plain. The diffraction maxima at 3.23 and 3.47 Å marked the dominance of K-feldspars (orthoclase/microcline). The anomaly in the distribution pattern of feldspar and micas in soils of semi-arid region could be attributed to the relative enrichment of specific kind of minerals in their parent material or in the source of alluvium.

Sand fraction of humid region soils was low in mica content compared to soils of semi-arid region. The distribution of feldspars (12%) and micas (8%) in humid region (Jorhat) soils was identical except feldspar content in Kokila. Lower amount of micas in these soils was related to intense weathering of soils where micas have undergone various transformation to secondary minerals such as chlorite. Micas were dominantly dioctahedral with elongated and serrated flakes. However, fresh biotite was also detected in the sand fraction of Kokila. Plagioclase and K-feldspar in these soils were highly fragmented because of their physical and chemical instability.

Potassium bearing minerals in silt fraction

Micas and K-feldspars were the prime K bearing minerals present in the silt fraction of soils (Table 2). Mica was higher in silt fraction than sand in soils of semi-arid region. The mica content (weighted mean of P1 to P4) of the silt fraction compared to 15.5% in sand. Similarly, it was 37% compared to 25% in Yamuna alluvial plain. The presence of relatively higher amount of micas in the silt fraction was possibly due to mechanical breakdown of sand size micas during transportation (Dhaliwal *et al.* 1993). The ratios of intensities of 10 and 5 Å reflections indicated the presence of both di-and trioctahedral micas with the dominance of former. The distribution of feldspars was almost identical to the sand fraction of all the soils. Besides micas and feldspars, little amount of chlorite, kaolinite and interstratified minerals were also observed in these soils. The content of quartz was very less in the silt fraction of semiarid soils reflecting the difference in nature of alluvium between the two regions.

In general, the mineralogical composition of the silt fraction of humid region soils was similar to its sand fraction (quartz > feldspar> micas > kaolinite > chlorite). Mica was higher than sand fraction but much lower compared to the semiarid region soils. Presence of higher amount of quartz and feldspars and lower amount of micas in these soils suggested that their alluvium were derived from igneous and metamorphic rocks such as granite, gneiss and schist (Dey 1999). The lower amount of micas in the silt fraction might also be attributed to the accelerated weathering of layer silicate minerals under hot and humid environmental condition. Micas of these soils were predominantly dioctahedral in nature except in the silt fraction of Kokila (P12) where both di-and trioctahedral type were observed as detected by 060 (hkl) spacing. Silt fraction of Kokila soil also contained appreciable amount of K-feldspar as indicated by strong diffraction maxima at 3.23 Å. Jorhat soil had higher amount of plagioclase feldspar, whereas silt fraction of North Bank Plain (P13 and P14) indicated the presence of both orthoclase and plagioclase feldspar. The differences in the mineralogical composition between the two zones primarily originated from the source of alluvium (Karmakar and Rao 1999). Kokila soil exhibited some unique characters as it experienced fresh deposition of sediments every year from the river Brahmaputra. The sediments contain both fresh as well as weathered mineral particles derived from various sources.

Table 3. Relative abundance of minerals in clay fraction of the soils (weighted mean of the soil profile, in per cent)

Pedon	Minerals						
	I	K	S	V	CH	ISM	O
P1	40	20	7	20	9	2	2
P2	52	19	10	14	-	2	3
P3	56	20	2	14	3	-	3
P4	48	19	11	17	1	-	4
P5	60	20	8	6	-	2	4
P6	84	7	2	2	1	1	3
P7	54	28	4	7	3	-	3
P8	72	13	6	3	2	-	4
P9	63	14	13	1	5	-	3
P10	41	29	20	4	3	-	3
P11	20	70	-	5	1	3	1
P12	32	53	3	4	4	2	2
P13	15	60	2	14	5	2	2
P14	27	56	-	9	4	3	1

Q= Quartz, F= Feldspar, M= Micas, CH= Chlorite, K= Kaolinite, ISM= Interstratified minerals
I= Illite, S= Smectite, V= Vermiculite and O= Others

Potassium bearing minerals in clay fraction

Semi-quantitative estimation of the clay fraction indicated that illite was the prime K bearing mineral (Table 3). The X-ray diffractogram of clay fraction showed strong and sharp diffraction maxima at 10 Å with its submultiples at 5 and 3.33 Å in potassium as well as magnesium saturated clays, which remain unaffected on glycolation and heating up to 550^{0}c, confirmed the presence of illite in these soils. The other minerals identified in the clay fraction were kaolinite, vermiculite, smectite, chlorite and interstratified minerals. Highest amount of illite was recorded in P5 to P10 (62%) followed by P3 and P4 (52%) and P1 and P2 (46%). The relatively less weathering of micas might have converted to illite, a dioctahedral mica, but differs from mica by having poor crystallinity, low K content (4-6% compared to 10% in mica) and H_2O in structure. These are therefore detrital in origin. Illite mineral of semiarid soils were predominantly dioctahedral type as indicated by strong reflection at 10 Å with weak to moderate intensity peak at 5 Å positions. The X-ray intensity ratio of peak height at 001 and 002 reflections was much greater than unity, which confirmed the presence of both muscovite and biotite. Kaolinite was the second most abundant mineral in all the semiarid soils. The alluvial soils of Indo-Gangatic plain have undergone three climatic changes in Holocene period during which biotite transformed progressively to mixed layer minerals followed by trioctahedral vermiculite, smectite, smectite-kaolinite and kaolinite (Srivastava *et al.* 1998).

The clay fraction of humid region soils was dominated by kaolinite (60%) and had only 23.5% illite. Kokila soil had highest amount of illite (32%) followed by Chatia (27%). The intensity ratio of peak height of this mineral was near to unity except in Kokila, indicating dioctahedral character of the finer fraction. The broadening of 10 Å peak of mica in the soils, which is more asymmetrical towards low angles, indicated replacement of interlayer of K of micas. The dominance of kaolinite in soils of humid region indicates intense weathering condition of the region. The presence of illite, interstratified minerals, vermiculite and chlorite in these soils exhibited that these minerals appeared to have originated from micas. Kaolinite in these soils was the ultimate product of either mica or feldspar weathering (Chakravarty *et al.* 1993).

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