Potassium mineralogy, dynamics and availability in Orissa Soils

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Potassium is an essential nutrient element for all living organisms including plant and animals. It is the univalent "Master Cation" found in largest concentration (100 – 200 *m* M-K) in the plant cell sap. Potassium is ionic, free (not bound to any constituent) and mobile in the plants. It is nomadic in nature (can move into and out of the plants). It plays vital roles in translocation of assimilates, photosynthesis, enzyme activation (more than sixty), osmotic regulation, hence in water relations, resistance to pests and diseases and tolerance to cold, frost and crop quality.

Most of the K in soil is held in the primary minerals like micas and potassic feldspars (microcline) and secondary minerals. As primary minerals weather, their rigid lattice structure becomes unstable increasingly. With passage of time, the K^+ held in the interlayer spaces of 2:1 type minerals (micas) becomes more mobile, fastly through non-exchangeable but slowly available (held in between the 2:1 type crystal layers) form and finally through the readily exchangeable (held on surface of soil colloids) and the soil solution forms from which K is absorbed by plant roots. The K^+ ion absorbed by plants from the soil solution is cycled through plants, human beings and animals and is returned to soil, where after undergoing few or several transformations again enters the soil solution to start the next cycle.

The parent material determines the physico-chemical properties of soils. The weathering of minerals release different ions, which subsequently become important for plant growth. The inherent status of K in soils of Orissa a re mainly governed by the soil mineralogy. The mechanism of breakdown of K bearing minerals to release K differs from mineral to mineral. The feldspars breakdown by surface reaction and replacement of K^+ by H_3O^+ and subsequent rupture of Si-O-Al-bond. The presence of void spaces inside mica lattice, changes in inter layer spacing and drying of lattices occurs due to the presence of $CaCO_3$ during weathering processes release K^+ from mica. The shortened and strengthened K-O bond creates difficulty in the rupture of the lattice. However, oxidation of F_e^{2+} to F_e^{3+} during weathering break the mineral and release K^{+}. The weathering rate of feldspar is much slower than mica. Among the micas tri-octahedral mica (biotite) releases sufficient quantity of K to soil compared to dioctahedral mica (muscovite) even at a low intensity of weathering. Such release of K is least in soils having low mica content even if subjected to intensive weathering.

Potassium in Soil:

The earth crust contains about 2.4 per cent K, making it one of the plentiful elements. It is mostly present in different primary minerals and complex silicate compounds. It is also found in clay fraction and soil organic matter.

The mineral sources of K in soils are the dioctahedral micas: *muscovite, glauconite* and *hydrous micas* or *illite,* the trioctahedral mica: biotite and phlogopite and feldspar: *sanidine*, orthoclase and *microcline*. Microcline is the most common K feldspar in Orissa soil (Table – 1). Sahu, *et al.,* 1983, 1990, 1995 & 1997)

Table: 1 Mineral composition indifferent soil groups of Orissa

Location	Classification	Orthoclase	Mica (Moscovite)	Clay minerals (In order of abundance)
Alfisols				
Phulbani	Oxic Paleustalfs	24.6	6.1	I, K
Bhubaneswar	Rhodic Paleustalfs	41.1	---	I, K
Khurda	Ferric Plinthustalfs	37.6	---	I, K
Semiliguda	Oxic Paleustalfs	9.8	1.9	K, I
Suakali	Ultic Paleustalfs	31.0	---	K, I
Muktapur	Lithic Plinthustalfs	15.4		I, K
Inceptisols				
Bhubaneswar	Eutrochrepts	16.0	1.0	I, M, K
Shymakhunta	Acric Ustrochrepts	30.5	---	K, I, M
Ranital	Typic Haplaquepts	7.0	2.5	M, I, K
Motto	Vertic Haplaquepts	41.5	---	K, I, M

Keshpur	Typic Halaquepts	42.4	4.8	M, C, I, K
Entisols				
Jasuapur	Typic Ustifluvents	27.1	14.8	I, M, K
Kendrapada	Typic Ustorthents	33.0	1.1	I, M, K
Chilika	Prammaquents	22.5	3.1	K, I, M
Astaranga	Typic Haplaquents	38.6	4.3	M, I, K
Vertisols				
Arkabali	Typic Pellusterts	12.4	2.7	M, I
Luisinga	Ustalfic Pellusters	26.9	11.0	I, M

- I – Illite, K – Kaolinite, M – Montmorillonite, C – Chlorite.

The feldspar constituted 7 – 42 per cent of the fine sand fractions of soils and may be less than 5 per cent of the clay fractions of the most of the agricultural soils of Orissa.

In *Alfisols* orthoclase constituted 9.8 to 41%, while mica (muscovite) was present in Phulbani and Semiliguda soils. High temperature accompanied by alternate wet and dry season in the humid tropical and sub-tropical climate is congenial for the formation of *Alfisols*. The presence of high content of light minerals (orthoclase feldspar) in the fine sand fractions may be attributed to moderate weathering condition in the environment. These conditions are also conducive for development of *illite* in the clay fractions due to alteration and partial hydrolysis of the feldspar and mica (Sahu *et al.*, 1983). The occurrence of *kaolinite* in these soils is expected as in the course of weathering, leaching of bases including K is promoted on the account of deforestation and human interference.

In the *Inceptisols* (flood protected alluvial/coastal saline soils) *orthoclase* content varied between 7 and 42.4 per cent. Except for the Shyamakhunta and Motto, other soils had mica content varying between 1.0 and 4.8 per cent. These soils in general are, neutral to slightly alkaline and are highly base saturated with Ca^{++} and Mg^{++} dominating the exchange complex. These conditions are favourable for the formation of *smectites* in the clay fractions (Sahu *et al*., 1983). Alteration of K – *feldspar* might have led to the formation of *illite* in clays.

In the flood protected coastal saline soils (Motto and Keshpur due to prolonged contact with sea water containing M_g^{++} with impeded drainage and alkaline condition might have favourded for formation of *chlorite* from *smectite* in Keshpur (Sahu *et al*.., 1986) and *montmorrilonite – illite* inter stratification along with *montmorillonite* in Motto soil clays.

The Entisols in Orissa are found mainly due to river alluvium (soils are transported by river water and are deposited on the surface during flood). The much higher content of *orthoclase* (27.1 to 38.6 %) and mica (1.7 to 17.4%) might be attributed to the source of alluvium. High mica content in the sand fraction indicates lack of intense weathering. For this reason alluvial soils have high available K status. High base saturation with slightly acid to neutral soil reaction ;must have favoured for the formation of *smectites* besides *illites* (Sahu *et al.*, 1990)

The Vertisols in Orissa Soil had high content of Orthoclase (12.4 to 26.9%) and mica (2.7 to 11.0%). Their transformation/alteration accounts for the occurrence of illite/ The abundance of Ca^{2+} and Kg^{2+} in an alkaline environment favours the formation of montmorrilonite as the dominant component in the clay fraction.

The study of fine sand fraction (0.1 – 0.25 mm)mineralogy of Central Research Station, Orissa University of Agriculture and Technology, Bhubaneswar by Nayak, (1998) revealed (Table – 2) that though quartz dominated the fine sand fraction mineralogy (55 – 80.5%) appreciable quantity of K bearing minerals like orthoclase *feldspar* (9.5 – 31.0%) biotite and *muscovite* (1-2%) were present. The *Alfisols* contained more K bearing minerals than the *Inceptisols.* The absence of easily weatherable minerals like *plagioclase* and presence of resistant species indicated greater intensity of weathering in these soils.

Table 2. **Mineralogy of fine sand fraction in the soils of Central Research Station, OUAT, Bhubaneswar**

Mineral species	**Orders**	
	Inceptisols	***Alfisols***
Quartz	80.5	55.0
Orthoclase feldspars	9.5	31.0
Andelusite	0.5	1.0
Garnet	0.5	1.0
Muscovite	---	1.0
Biotite	2.0	1.0
Zircon	---	0.5
Chlorite	2.0	2.0
Rutile	0.5	---
Opaque	3.5	4.5
Unidentified minerals	1.0	2.0

Mishra (2008) in his study of the mineralogy of fine sand fraction (0.1 – 0.25 mm) in the soils of Kanchinal Micro-watershed under coastal plains of Mahanadi delta Orissa observed that, considerable amount of K bearing minerals like *orthoclase, muscovite* and *biotite* were present in upland, medium land and low land soils (Table – 3). Low land soils had higher content of orthoclase followed by medium land and upland pedon. The proportion of *muscovite* was higher than that of *biotite* and their content in different land situations followed the order : upland > medium land > low land.

Table 3. **Mineralogy of fine sand fraction of Kanchinala Micro water shed under coastal plains of Mahanadi Delta, Orissa**

Mineral species	**Upland**	**Medium land**	**Low land**
Quartz	64.2	61.4	59.3
* Orthoclase (K – feldspar)	16.5	19.2	20.6
Phasioclase	4.8	5.2	5.0
Calcite	0.3	1.6	2.0
* Muscovite	3.5	3.0	2.8
*Biotite	2.8	2.2	2.3
Garnet	2.2	1.8	2.0
Horneblende	1.5	1.2	1.2
Opaque	3.0	3.5	4.0

* K – bearing minerals

The mineralogy of the clay fraction of the study area revealed that it had a mixed mineralogy and the order of mineral dominance was: *Smectite* > *Illite*> *Kaolinite*. Presence of *illite* in appreciable quantities indicated that these were synthesized from K rich soil solution as *orthoclase* and *micas* were present in significant quantities in sand minerals.

The weathering process is generally influenced by its intensity, cationic environment, especially the base saturation of clay. An alkaline environment favours the formation of *montmorillonite*, acid environment favours Kaolinite, while M_g rich environment produce *vermiculite*. Plants growing on soil also attack clay minerals by releasing H^+. The microbs inhabiting the soil by releasing organic/inorganic acids accelerate the process of weathering. Under riche-rice cropping system over the years (18 years and 36 crops), Pattanayak (1992) observed that there was increase in allophone (non-crystalline clay) content in all the cultivated soils except for follow (Table – 4). Cultivation without K addition resulted in breakdown of *illite* with subsequent formation of either *Kaolinite* or interstratified *smectite* or mixed layer mineral with chlorite. In K – added treatments, there was an increase in *illite* content in 100% NPK, *illite* with mixed layer mineral with chlorite in 100% NPK + Zn, *illite* with interstratified smectite in 150% NPK treatment. In 100% NPK + FYM treatment the amount of interstratified *smectite* showed improvement. Under fallow treatment there was increase in *kaolinite* content and subsequent decrease in interstratified s*mectite* and mixed layer minerals (Table – 5).

Table 4 Allophane content in soil under rice-rice cultivation for 18 years.

Treatments	**Initial**	**Fallow**	**Control**	**100% N**	**100% NP**	**100% NPK**	**100% NPK + FYM**	**150% NPK**
Allophane	0.04	0.012	0.048	0.061	0.056	0.056	0.066	0.056

Table 5. Relative peak area of minerals present in Mg saturation and glycolation treatment as influenced by long term manure and fertilizer application with cropping (Rice – Rice) system

Treatments	**14-17A^0**	**10.1-14A^0**	**10.1^0**	**7.1A^0**	**4.26A^0**
Fallow	25.7	27.0	19.1	27.4	0.8
Control	31.1	24.4	12.3	31.4	0.8
100% N	35.6	27.4	12.8	24.0	0.4
100% NP	38.7	25.6	12.8	22.3	0.6
100% NPK	29.5	30.3	16.2	24.0	---
100% NPK + FYM	35.0	33.6	11.5	19.2	0.7
150% NPK	36.2	14.7	18.9	29.6	0.6
Initial	33.5	28.7	13.8	23.4	0.6

Availability of K in soil

Although most soils contain 1000 ppm of total K only a small portion (<2%) is available to plants. Potassium exists in four different forms in soil (i) solution K (readily available/water soluble) (ii) exchangeable K (easily available) (iii) non-exchangeable/fixed K (difficultily available/slowly available) and (iv) mineral/structural K (unavailable)

Sahu *et al.* (1997) from their work on coastal saline and alluvial soil reported that (Table 6) these soils were rich in K and exchangeable K is sufficient to meet the crop demand.

Table 6. Total Exch. and K saturation per cent in different soils of Orissa

Soil type	**Location**	**Total**	**Exch. K**	**K-saturation**
		K_2O (%)	**cmol (P^+) Kg^{-1}**	**(%)**
Coastal saline	Keshpur	2.71	0.90	3.8
	Motto	3.01	0.90	6.2
Alluvial	Jasuapur	2.41	0.35	3.52
	Kendrapada	0.72	0.19	0.81

Total soil Potassium and exchangeable – K

The potassium status of some broad soil groups of Orissa (Table – 7) reveal that coastal saline soils had high exch. and water soluble K. Among inland soils red soils had higher K than lateritic soils. Alluvial soils had wide range of K status. The K saturation in these soils was co-related with exch. and water soluble K (Mitra *et al.*, 2006).

Table 7 Potassium status of some broad Soil groups of Orissa

Sl. No.	Broad soil group	Total K_2O (%)	Non-Exch. Fixed – K	Exch – K cmol (P^+) Kg^{-1} soil	Water soluble K	K saturation (%)
1	Lateritic soil	0.3-1.2 (0.69)	0.1-0.9 (0.31)	0.06-0.30 (0.17)	0.008-0.08 (0.05)	1.3-4.8 (2.7)
	Red soil mixed read andblack soil	1.62-6.03 (1.32)	0.2-0.97 (0.68)	0.1-1.1 (0.4)	0.025-0.27 (0.14)	0.75-14.9 (5.54)
	Alluvial soils	0.68-2.41 (1.32)	0.05-1.92 (0.85)	0.06-0.64 (0.26)	0.018-0.18 (0.07)	0.81-5.8 (2.35)
	Coastal salinesoils	1.77-3.1 (2.5)	0.18-1.45 (0.72)	0.14-1.6 (0.89)	0.3-1.6 (0.73)	3.0-6.2 (4.32)

Mallik (1996), Nayak (1998), Parida (2000) observed positive correlation (r = 0.91*) between exchangeable K and available K_2O content of soils under different orders Table 8.

Table 8. Exchangeable and available-K content in soils under different orders

Soil order	Exch. K c mol (P^+) Kg^{-1})	Available (K_2O) kg ha^{-1})
Alfisols	0.2	105
Entisols	0.66	312
Vertisols	0.97	380
Inceptisols	0.90	370

Pattanayak (1992) studied the K – status of laterite under long term manure and fertilizers application condition under rice-rice cropping system for 18 years (Table-9). He reported that structural K constituted 97 per cent of the total K pool. Due to the establishment of equilibrium among different forms of K

– not much change was observed in available K (exch. + water soluble) status compared to initial status. The total K status in soil decreased irrespective of K application except for 150% NPK dose. Pal *et al.* (2001) from Athagarh soils reported that total K ranged from 950-2400 ppm and ammonium acetate extractable K 10-380 ppm, which accounted for 3-12 per cent of total K. The non exchangeable and structural/lattice K accounted for 14-45 and 48-80 ppm of total K respectively.

Table : 9 Effect of long term (18 years) manure and fertilizers application to rice-rice system on soil K status

Treatments	W.S + Exch. K	Non Exch. K	Structural K	Total - K
Fallow	51.5	7.8	2254	2313
Control	44.3	14.7	2414	2473
100%N	44.7	39.7	2548	2633
100% NP	23.2	37.9	2465	2526
100% NPK	37.8	41.7	2630	2710
100%NPK + FYM	26.7	41.2	2605	2673
150% NPK	47.1	60.9	2738	2827
Initial	50.3	23.9	2692	2767

Table: 10 Profile distribution of available K (ppm) in soils under different orders

Horizon	*Alfisols*	*Inceptisols*	Entisols
1st	50-120	80-110	35-145
2nd	35-91	60-75	30-75
3rd	30-80	55-70	30-95
4th	25-70	50-60	25-65

Nayak *et al.*, (1998) while studying the profile distribution of available K in *Alfisols*, *Inceptisols* and *Enticols* of Orissa reported that the K-status was medium to low. The quantity of available –K decreased downward in all pedons. This was due to moderate weathering, light textured, high rainfall coupled with crop removal and fertilizer application on surface layer.

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