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Non-Exchangeable Potassium Release by Organic Acids in the Indo-Gangetic Alluvial Soils of Northwestern India

D. S. BENIPAL, RAJ KUMAR, B. S. BRAR AND N. S. PASRICHA

Department of Soils, Punjab Agricultural University
Ludhiana 141004, India

Abstract

Non-exchangeable K release from whole soil and its coarser fractions were investigated in soils of Indo-Gangetic alluvial plains using organic acids. Available and non-exchangeable content of K were higher in soils of south western zone followed by central plain and sub-montane zone and more than 93% of the total K was in mineral form. In sand fractions presence of minerals like quartz, feldspars, micas, chlorite and kaolinite was noticed whereas illite was the dominant mineral in the clay fraction followed by vermiculite and smectite. Non-exchangeable K release was faster initially and thereafter it was gradual with increasing time. Higher amounts of K were released by oxalic acid than by citric acid and whole soils released more quantities of non-exchangeable K than coarse and fine sand fractions using both the organic acids.

Key words : Non-exchangeable K release, K forms, Mineralogical composition, Organic acids.

The soils of northwest Indo-Gangetic plain region have high reserves of K due to abundance of micas and feldspars in coarser fraction and predominance of K rich illite in the clay fraction (1). The ease with which K is released from non-exchangeable sources is an index of the ability of soil to supply K to the crops. Crop removal of K often exceeds annual additions from all sources, this may or not may be accompanied by approciable change in available K status of the soils, thereby, suggesting that non-exchangeable K becomes available to plants (2). The rate of non-exchangeable K release and its mechanism are controlled by the nature and amount of minerals and organic acids present in the soil environment. Organic acids facilitate the metal release through formation of metal organic complexes. These acids are produced in soils during the decomposition of plant and animal residues, humic substances, microbial metabolism and rhizosphere activities (3). Non-exchangeable K release from minerals upon acid treatment is of significance, particularly in the root-soil interface where hydronium (H_3O^+) ions are probably the cause of major release of inter layer K upon the alteration of minerals (4). In a number of earlier studies conducted on the rate and quantity of K released by soils and minerals, emphasis has been given only to finer soil fractions and clay minerals (5—7). Little information is available on the pattern of K release from soils containing appreciable quantities of sand especially the soils of Punjab, which are formed on alluvial deposits and are mostly coarse in texture. The present study was undertaken to investigate the non-exchangeable K release from coarser fractions of soils collected from different agro-eco-zones of the state.

Methods

Sixteen surface soil samples were collected from different sites representing various agroecozones of the Punjab state. The soils were neutral to alkaline (pH 6.7—8.7), poor in organic carbon (1.1—4.7 g/kg) and low in soluble salts (EC 0.14—0.82 dS/m). These were light to medium in texture. The cation exchange capacity of the soils ranged between 3.6 and 14.3 cmol/kg and calcium carbonate content was less than 5% (Table 1). Different forms of K in soils were determined by the methods given by Pratt (8). These soil samples were fractionated into coarse sand (2—0.2 mm) and fine sand (0.2—0.02 mm). Before initiating K release studies, the soil and its coarser fractions were Ca saturated with 1M

Table 1. Basic characteristics of the soils. Figures in parentheses indicate the number of samples.

Soil characteristics	Sub-montane zone (7)	Central plain-zone (5)	South western zone (4)
pH (1 : 2)	6.7—7.8	7.3—7.8	7.8—8.7
EC (dS/m)	0.14—0.75	0.17—0.66	0.27—0.83
OC (g/kg)	1.1—4.7	1.2—4.1	1.6—4.1
CEC (cmol p + kg)	8.0—13.2	3.6—14.3	4.2—12.0
$CaCO_3$ (%)	1.5—5.0	0—1.9	3.0—5.8
Sand (%)	22.1—73.5	24.3—79.4	52.9—73.4
Silt (%)	10.5—57.9	4.1—48.0	12.6—25.1
Clay (%)	6.0—30.0	14.0—46.0	14.0—32.0

$CaCl_2$. The samples were then washed with deionized water until a negative test for Cl was obtained. Duplicate 1 g of Ca saturated samples were added to 40 ml polypropylene centrifuge tubes and 20 ml each of organic acids (0.01 M oxalic acid and 0.01 M citric acid) were added in each centrifuge tube. The samples were equilibrated at 298^0 K for 0.25, 0.5, 1, 2, 5,10, 25, 50 and 100 hr. The suspensions were centrifuged for 10 minutes at 10,000 rpm and quantities of non-exchangeable K release were estimated using flame photometer. All the soil samples were analyzed for their mineralogical make up by the methods given by Jackson (9).

Results and Discussion

The soils from south-western zone had higher content of water soluble K (4.2—12.0 mg/kg) which might be due to higher salt accumulation at the surfaces of soils (Table 2). Ammonium acetate extractable K content is the most frequently used fraction for assessing K availability in soils, it constituted on an average, 0.7% of the total K content. The soils of south western zone were high in available K (113.1—226.2 mg/kg) as compared to central plain and sub-montane zone and this confirmed the observations made by Sekhon (10) who concluded that most of the soils of this region were high in available K. On an average the non-exchangeable K content was highest in soils of south western zone ((1,154.4 mg/kg) followed by central plain (1,002.3 mg/kg) and lowest in the soils of sub-montane zone (936.0 mg/kg). The higher content in south western zone may be ascribed due to the presence of higher content of biotite in this zone (11). More than 93% of the total K was in mineral form which suggested that parent material was the origin of the most of the potassium (Table 2). The sand and clay fractions of all the samples were analyzed for their mineralogical assemblage through X-ray diffraction which indicated the presence of quartz, feldspars (orthoclase and plagioclase), micas (muscovite and biotite), chlorite and kaolinite in various agro-climatic zones (Table 3). Semi-quantitative estimate did not indicate any significant difference in the mineral assemblage of coarse sand and fine sand fractions. Illite was the dominant clay mineral in the soils and vermiculite was the second most abundant clay mineral except in some soils where smectite was the second abundant mineral. Other constituting minerals in the clay fraction were kaolinite and chlorite (Table 3).

Non-exchangeable K release was faster initially and thereafter it slowed down with time. (Fig. 1). Hundal and Pasricha (12) and Benipal et al. (13) also reported that non-exchangeable K release was rapid initially but decreased with increasing time in alluvial soils of Punjab. After 100 hours of reaction period

Table 2. Different forms of K in the investigated soils. Figures in parentheses indicate the mean values.

K forms	Sub-montane zone	Central plain zone	South western zone
Water soluble	7.8—15.6 (8.9)	7.6—11.7 (8.2)	11.7—19.5 (15.6)
Available	39.0—198.9 (120.1)	31.2—113.1 (62.4)	113.1—226.2 (195.0)
Exchangeable	31.2—183.3 (109.2)	23.4—101.4 (50.7)	101.4—276.9 (179.4)
Nitric acid soluble	300.3—1599.0 (1170.0)	600.6—1361.1 (1142.7)	959.4—1981.2 (1337.7)
Non-exchangeable	191.1—1478.1 (936.0)	557.7—1326.0 (1002.3)	826.8—1704.3 (1154.4)
Mineral	15077.4—18918.9 (16497.0)	14917.5—18411.9 (16980.6)	13197.6—1884.3 (15291.9)
Total	15498.6—20096.7 (17639.7)	15997.8—19796.4 (18879.9)	14301.3—19301.1 (16848.0)

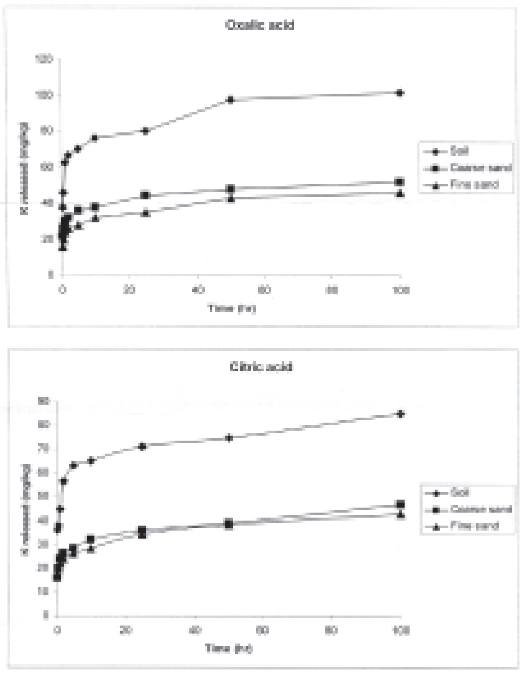

Figure 1. Patterns of non-exchangeable K release in a soil using organic acids.

average cumulative non-exchangeable K released from whole soils to oxalic acid was 322.6, 326.8 and 379.6 mg/kg in sub-montane, central plain and south

Table 3. Semi-quantitative estimate of minerals in soils under investigation.

Zones	Coarse sand	Fine sand	Clay
Sub-montane	Quartz, plagioclase, orthoclase, micas	Quartz, orthoclase, plagioclase, micas, chlorite, kaolinite	Illite, vermiculite, kaolinite, mixed, kaolinite, chlorite
Central plain	Quartz, orthoclase, plagioclase, micas	Quartz, orthoclase, plagioclase, micas, chlorite, kaolinite	Illite, vermiculite, chlorite Mixed minerals, smectite
South western	Quartz, orthoclase, plagioclase micas	Quartz, orthoclase, plagioclase, chlorite, kaolinite, micas	Illite, vermiculite, kaolinite, mixed minerals, chlorite

Table 4. Cumulative non-exchangeable K release (mg/kg) from soil and coarser fractions in different agro-ecosystem.

Zones	Whole soil	Coarse sand	Fine sand
Oxalic acid			
Sub-montane	322.6	219.9	235.2
Central plains	326.8	222.7	196.4
South western	489.4	275.7	238.1
Mean	379.6	239.4	223.2
Citric acid			
Sub-montane	305.2	167.7	206.8
Central plains	290.3	182.0	182.2
South western	417.0	235.0	227.5
Mean	337.5	194.9	205.5

western zones respectively, during similar reaction period respective of amounts of K released to citric acid were 305.2, 326.8 and 379.6 mg/kg (Table 4). Whole soils released higher quantities of non-exchangeable K than coarse and fine fractions using both the organic acids. Higher amounts of non-exchangeable K were released by oxalic acid than that released by citric acid. Non-exchangeable K release was higher in whole soil (12%) using oxalic acid. Similarly coarse sand and fine sand released 22.8 and 8.6% of higher amounts of non-exchangeable K released by oxalic acid than citric acid respectively. The difference in the ability of oxalic acid and citric acid to K release from soils is considered because of the difference in the amount of organic ligands, hydrogen ion generated by these acids and in the complexing ability of the ligands (7). The efficacy of these organic acids to dislodge K from inter layers could be attributed to organic ligands forming metal organic complexes accelerating mineral decomposition and the weakening of the surface OH groups by protonation (3). More or less similar magnitude of differences among the organic acid extractable K contents were also reported by Song and Huang (7).

References

1. Sidhu P. S., S. S. Bhangu and H. S. Jassal. 1993. Mineralogy of soil K in some benchmark soils of Punjab. J. Pot. Res. 9 : 206—217.
2. Pasricha N. S. 2002. Potassium dynamics in soils in relation to crop nutrition. J. Indian Soc. Soil Sci. 50 : 333—344.

3. Srinivasa Rao Ch., S. P. Datta, A. Subarao, S. P. Singh and P. N. Takkar. 1997. Kinetics of non-exchangeable potassium release by organic acids from mineralogically different soils. J. Indian Soc. Soil Sci. 45 : 728—734.
4. Huang P. M., L. S. Crosson and D. A. Rennie. 1968. Chemical dynamics of potassium minerals common in soils. Trans. 9th Int. Cong. Soil Sci., Adelaide 2 : 705—712.
5. Pal D. K. and S. L. Durge. 1989. Release and adsorption of potassium in some benchmark alluvial soils of India in relation to their mineralogy. Pedologie 39 : 235—238.
6. Simard R. R., C. R. Dekimpe and J. Zizka. 1992. Release of potassium and magnesium from soil fractions and its kinetics. Soil Sci. Soc. Am. J. 56 : 1421—1428.
7. Song S. K. and P. M. Huang. 1988. Dynamics of potassium release from potassium bearing minerals as influenced by oxalic and citric acids. Soil Sci. Soc. Am. J. 52 : 383—390.
8. Pratt P. F. 1982. Potassium. Pages 225—246 *in* A. L. Page., R. H. Miller and D. R. Keeney, editors. Methods of soil analysis II. Chemical and microbiological properties. Am. Soc. Agron., Soil Sci. Soc. Am., Madison, Wisconsin, USA.
9. Jackson M. L. 1975. Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi, India.
10. Sekhon G. S. 1976. Potassium problems of Punjab soils. Bull. Indian Soc. Soil Sci. 10 : 56—60.
11. Sidhu P. S. and S. S. Bhangu. 1995. Mineralogy of potassium in soils of Punjab. Proc. Use of Pot. in Punjab Agric., pp. 24—33.
12. Hundal L. S. and N. S. Pasricha. 1993. Non-exchangeable potassium release kinetics in illitic soil profiles. Soil Sci. 156 : 34—41.
13. Benipal D. S., N. S. Pasricha and R. Singh. 2006. Potassium release to proton saturated resin and its diffusion characteristics in some alluvial soils. Geoderma 132 : 464—470.