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POTASSIUM FIXATION BY THE CLAY MINERALS OF THE LYALLPUR SOIL SERIES

S.A. Shahid, D.A. Jenkins* and K.H. Gill**
Department of Soil Science,
University of Agriculture, Faisalabad.
**University of Wales, Bangor, Gwynedd, U.K.*
***Soil and Water Conservation*
Research Institute, Chakwal

The fixation of added potassium by three different size fractions of clay (coarse, medium and fine) was studied at the rate of 50 and 100 μg/ml. The results revealed that the fine clay fraction (<0.063 μm) contained mainly smectite and vermiculite which fixed K (85%) followed by 75% fixation by the medium fraction (0.2-0.063 μm). Kaolinite minerals were found in coarse (2-0.2 μm) fraction which did not fix appreciable amount of K. The fixation of 50% by this fraction was attributed to the traces of smectite and a minor content of vermiculite.

INTRODUCTION

Potassium is classified as a major plant nutrient. Its deficiency in soil for plant growth is compensated by adding potassium fertilizers. In addition, potassium reserves are also found within soil minerals and their availability to plants is directly related to the nature of K-bearing minerals. The amount of potassium in mineral soils is bound in primary silicate minerals, such as feldspar, micas and illitic clays. The more weathered clay minerals of the vermiculitic and montmorillonitic types contain less potassium while kaolinitic clay minerals may contain very small quantities of potassium.

Potassium fixation may be regarded as a reverse process of weathering. In the weathering process, the following changes of minerals have been suggested: mica ⟶ illite ⟶ vermiculite ⟶ montmorillonite (Arifin *et al.*, 1973). In the process of fixation, the gradual entrapment of potassium ions in the selective sites of the minerals causes a progressive collapse of the mineral structure and rearrangement to a mica structure with a 10 °A spacing.

On the basis of the recommendations given by the working group of workshop on the role of potassium in improving fertilizer use-efficiency (Saleem, 1989), the present study was carried out to assess the K-fixation power of the clay minerals in various size ranges of the Lyallpur soil series.

MATERIALS AND METHODS

A soil sample was collected at the subsurface (5-10 cm) depth of the Lyallpur soil series. The sample was ground and passed through a 2 mm sieve. The physical and chemical characterization was made according to the standard methods (Richards, 1954) except otherwise mentioned. All measurements were made on duplicate air-dried samples and results are presented on an oven-dried soil. Soil texture was determined according to Day, 1965.

After the soil texture determination was over, the clay was siphoned as suspension. The three different size fractions of clay i.e., coarse (2.0-0.20 μm), medium (0.2-0.063 μm) and fine (<0.063 μm) were then separated through centrifugation using the integrated form of Stoke's law as proposed by Hathaway (1956). Clay minerals were identified by standard XRD technique.

The separated clay fractions were then subjected to K-treatment @ 50 and 100 μg/ml as K_2SO_4 salt and fixation power by these fractions for K was then assessed.

RESULTS AND DISCUSSION

The results of the present study will be described under different sections separately.

Clay mineralogy by XRDA: Clay mineralogy of the sample was established by XRD technique. The summary of the clay mineralogy after describing the X-ray traces of the treated clay samples (Shahid, 1989) is shown in Table 1.

Table 1 revealed the dominance of illite in all but <0.063 μm, where it is present in major amount. Smectite is present in traces in the coarse, major in medium and dominant in the fine clay fraction. Vermiculite is present as minor in both coarse and fine and traces in the medium fractions. Kaolinite was absent in the fine and traces in the medium and minor amounts in the coarse fraction. Chlorite was detected as traces in the medium and fine fractions and minor amount in the coarse.

Table 1. Summary of the clay mineralogy of the soil used

Size (μm)	I	Ch	Ka	Vm	Sm	Qu	Fd	I/Vm	Ch/Vm	Vm/Sm	I/Vm
								random			(regular)
								Interstratified			
2-0.200	4	2	2	2	1	3	-	1	1	-	-
0.2-0.063	4	1	1	1	3	-	-	1	1	-	1
<0.063	3	1	-	2	4	-	-	1	1	1	1

Key: 4 = dominant, 3 = major, 2 = minor, 1 = traces,
- = undetectable
I = Illite, Ch = Chlorite, Ka = Kaolinite,
Vm = Vermiculite, Sm = Smectite, Qu = Quartz, Fd = feldspar.

Physical and chemical characteristics of the soil: The values of EC_e (0.8 dSm^{-1}), pH_s (8.0) and ESP (4.0) classified the soil sample to be non-saline and non-sodic according to Richards, 1954. Soil texture determined was silty clay loam, (sand 12%; silt 56% and clay 32%). The particle sizes are based on MIT scale (Hodgson, 1976).

As far as the interstratified minerals are concerned, random I/Vm, Ch/Vm and Vm/Sm interstratified were present in traces in all, but absent (Vm/Sm) in the coarse and medium fractions. Regular interstratified clay-minerals such as I/Vm was absent in coarse fraction, and was present in traces in the medium and fine fractions.

Regular interstratified clay-minerals such as I/Vm was absent in coarse fraction, and was present in traces in the medium and fine fractions. This suggests the weathering sequence of clay minerals in the Lyallpur series as: I ——— I/Vm ——— Vm ——— Vm/Sm ——— and also confirm the pedogenic nature of vermiculite and smectite.

K-fixation studies: The results revealed the fixation of K at the rate of 85% by the fine ($<0.063\ \mu m$) fraction. This high fixation is a result of the presence of smectite (dominant) and vermiculite as minor. These two minerals fixed K-strongly. Fixation varied with the nature and amount of clay minerals (Duthion, 1968; Bajwa, 1985) e.g. zero with kandites (kaolinite), hormites, chlorites and micas; slight with montmorillonite and variable with hydrous mica (illite), according to the degree of alteration; and strong with vermiculite and beidellite. The nature of smectites in the Lyallpur soil series was beidellite (aluminum rich member of smectite family) because of which the fixation in the fine and medium clay was high, i.e. 85 and 75%, respectively.

The difference of fixation between the medium and fine clay may be due to the difference of relative concentration of vermiculite and smectite in these two fractions. This means that potassium is present in clay minerals predominantly at potassium specific sites with high binding energy and that the non-specific sites will only be occupied with increasing degree of saturation. The specific sites for K in clay minerals are the hexagonal framework in the Si-sheet. The size of the potassium ion fits well into the hexagonal position because of its closeness to the negative charges in the mineral and because of geometric configuration (Hagin & Tucker, 1982). This has practical implications in the assessment of the contribution of exchangeable potassium to its nutrition of plants. The non-specifically bound potassium has higher equilibrium concentration in the soil solution than that of the specifically bound (fixed) potassium, particularly in soils high in illites, vermiculites and some mixed layer minerals. Hence a comparison of the content of exchangeable potassium as an indication of availability to plants can only be made with due consideration of the amount and kind of clay minerals.

The K-fixation by the coarse clay was 50% which might be due to the traces of smectites and minor amount of kaolinite and chlorite.

Due to the higher amounts of certain clay minerals (vermiculite and beidellite), the soil has shown higher K-fixation. This may explain why low levels of K application in certain situations show no response. Thus higher rates of fertilizers will then be needed to overcome the K-fixation capacity before K is available to plants. This suggests that the availability of native or added potassium to plants is strongly dependent upon the clay mineralogy. Therefore, detailed studies on clay mineralogy of the soils of Pakistan are urgently required for proper formulation of potash recommendations.

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