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# Dynamics of Clay Mineralogy With Profile Depth in Relation to Long Term Potassium Fertilizer Application to Sugar Cane Crop

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**Abstract.** The experiment consisted of treatment of sugar cane crop with N, NP, NPK and farmyard manure and determination of its effect on soil mica, vermiculite and montmorillonite over a period of 18 years. The NPK treatment had greater mica in coarse clay, but less in fine clay than NP and control treatments. Vermiculite in coarse clay fraction, in NPK treatment, increased with the depth as compared to other treatments. The fertilizer treatment effect on smectite content was obvious only in AP horizon in fine clay fraction.

**Keywords:** clay mineralogy, potassium fertilizer, sugar cane

## Introduction

Potassium requirements of plants are mostly met from soil K resources. With respect to availability to plants, soil K exists as structural, exchangeable and soluble potassium. Mineral K occurs as mica and feldspars and amounts to about 98% of all the soil K, while readily available form of K is only 1-2% and occurs as exchangeable and soluble potassium. Sugar cane takes up K from solution that is buffered with exchangeable and structural potassium of soil system. Therefore, solution K depletion due to plant growth enhances weathering of mica and K feldspars. Among the two types of mica, biotite weathers at a rate faster than muscovite. Hence, biotite in soil system maintains greatest solution K than muscovite. Potassium feldspars in fine silt and clay fraction serves as an important source of K, though usually less significant than mica. Bajwa (1989) and Al-Ravi and Al-Mohammadi (1979) inferred that amongst the feldspars, only orthoclase is important in releasing potassium.

Mica on weathering is transformed to vermiculite with concurrent release of interlayer K (Fanning *et al.*, 1989). Mineral vermiculite entraps added K and renders it unavailable to plants. On K fixation, the expensive minerals, beidellite and vermiculite contract and revert to mica-like-structure (Alexiades and Jackson, 1965).

Mittal *et al.* (1989) observed that increasing cropping intensity resulted in depletion of soil K, yet the intensity of K depletion was associated with cropping and fertilizer scheme. Akhtar and Ali (1993) also reported K depletion with intensive cultivation of rice-wheat without fertilizer K in an alluvial camborthid soil. Tributh *et al.* (1987) observed that removal of K by plants results in depletion of interlayer K in illite followed by the degration of clay minerals. Cropping without K application enhanced the depletion of structure K from mica minerals leading to the transformation of mica to vermiculite and smectite. The removal of K by plants resulted in depletion of interlayer K from illite and an increase in smectite minerals. These phenomena induce changes in clay mineralogy in soil profile with depth.

Singh and Goulding (1997) observed no changes in mica and no K depletion in 153 years experiment on soil that was put under winter wheat cultivation at Rothamsted Experiment Station. However,contrary to this, Srivastava *et al.*(2002) observed depltion of non-exchangeable K in 27 years in NP treatment compared to NPK+FYM in alluvial mixed mineralogy in typic ustochrept soil under maize-wheat-cowpea cropping system.

Shaikh *et al.* (2007), in a five year study of mineral composition of Ustic Haplocamborthid soils of Sindh, under cotton-wheat system, observed that NPK treatment has more mica in coarse and fine clay fractions in AP (0-14 cm) horizon than control and NP treatments, indicating greater weathering of mica in NP than NPK treatment in surface horizon wherein K-less treatment increased weathering of sand and silt size mica. Dhaliwal *et al.* (2006) observed that soils containing sufficient quantity of K fix lower quantity of K.

Fertilizer application to sugar cane in Pakistan is primarily skewed towards nitrogen, followed by phosphorus and only nominal quantities of potassium are applied. The sugar cane crop of 125-Mg/ha removes about 168 kg K/ha per year.

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Potassium application in K deficient soils causes an increase in sugar cane yield and also tolerance against environmental stresses including moisture stress as well.

Ahmad (2000) reported that soils in alluvial plains of Pakistan are intensively cultivated without application of K fertilizer that causes a negative K balance in soil. Continuous crop production with K application may result in mica weathering particularly that of biotite into vermiculite.Hence the study was conducted with the objective to investigate the dynamics of clay mineralogy with profile depth in relation to long term potassium fertilizer application to sugar cane crop.

## Materials and Methods

Soil samples were collected from the site under sugar cane crops from 1978 to 1996 at Soil Chemistry Section, Ayub Agricultural Research Institute, Faisalabad. The study site was typical camborthid (Soil Survey Staff, 1970). The soil was loam variant of Hafizabad soil series. It was medium textured calcareous, well drained, developed in late Pleistocene, mixed mineral alluvium. The annual precipitation was 350-400 mm; rainfall occurred mostly during summer and average annual temperature was 24 °C. Fertilizer treatments are presented in Table 1.

**Table 1.** Treatments of the experiment

| Treatments | Fertilizer applied (kg/ha) | | |
|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ |
| Control | 0 | 0 | 0 |
| N | 170 | 0 | 0 |
| NP | 170 | 110 | 0 |
| NPK | 170 | 110 | 110 |
| FYM | 85 kg N from fertilizer and 85 kg N from FYM.* | | |

* = 85 kg N from FYM amounts to 12.5 tons of FYM per hectare, as analysis depicted 0.68% N in FYM (farm yard manure)

Fertilizer treatments were applied each year to sugar cane crop and was incorporated in AP horizon.All the fertilizer treatments and control had three replications. All the processes including cultural and fertilizer applications were uniform for the experiment.The designe of the experiment was completely randomized block designe. Soil samples were collected after harvesting sugar cane crop of 1996.The profile site was taken at random and was representative one. The composit, representative soil samples were collected from genetic horizon; AP: 0-15 cm, BW: 15-40 cm and BWK: 40-50 cm depth. Soil samples were air dried, crushed by wooden roller, passed through 2mm sieve and analyzed for electrical conductivity ($Ec_e$), saturation percentage, soil reaction (pH), organic matter, total nitrogen and available phosphorus, according to the methods described by Page *et al.* (1982). Physical and chemical characteristics of the soil are given in Table 2.

**Table 2.** Physical and chemical characteristics of soil

| Soil characteristics | Horizon depth (cm) | | |
|---|---|---|---|
| | AP(0-15) | BW(15-40) | BWK(40-56) |
| Sand (%) | 47.1 | 46.4 | 45.2 |
| Silt (%) | 43.0 | 43.6 | 42.8 |
| Clay (%) | 9.9 | 10.0 | 12.0 |
| Textural class | Loam | Loam | Loam |
| $Ec_e$ ($dsm^{-1}$) | 1.30 | 1.32 | 1.70 |
| PH | 7.52 | 7.92 | 7.86 |
| Organic matter (%) | 0.65 | 0.50 | 0.50 |
| Total nitrogen (%) | 0.033 | 0.025 | 0.025 |
| Available phosphorus (ppm) | 3.5 | 3.0 | 4.5 |

Mineralogical determination of soil samples was conducted at National Agricultural Research Centre, Islamabad and soil samples were prepared for mineral analysis. For removal of cementing agent, 15 g soil sample was taken. Carbonates were removed with 1N NaO AC buffered at pH 5.0, organic matter was removed with 30% $H_2O_2$ and iron oxide was removed with citrate bicarbonate, dithionite bufferd at pH 7.3 (Jackson, 1979). For separation of soil into various fractions the treated samples were dispersed in $Na_2CO_3$ (pH 10) solution by 15 sec sonification using macro tip from the dispersed suspension. Sand was separated by wet sieving and silt by five repeated centrifugation washes which each time dispersed the suspension. The clay was further separated into coarse and fine clay fractions by similar five-repeated centrifugation treatments. Coarse and fine clay fractions were made salt-free by dialysis and were freeze dried. Mica, vermiculite and smectite in coarse and fine clay fractions were determined according to the methods described by Jackson (1979) (Table 3).

## Results and Discussion

**Changes in mica.** In coarse clay fraction, NPK treatment at all the three depths had greater mica as compared to other fertilizer treatments at respective depths (Table 4, Fig. 1). In NPK treatment, mica in AP was 34 g/l00 g which increased with depth and at the lowest depth, maximum of 41g/l00 g was recorded. The increase in mica from AP to BW was less as compared to the increase from BW to BWK. The lowest amounts of mica at the upper two depths were recorded in

**Table 3.** Mica, vermiculite and smectite in clay*

| Horizon | Depth (cm) | Fraction of profile<br>Mica | <br>Vermiculite<br>(g /l00g) | <br>Smectite |
|---|---|---|---|---|
| *Coarse clay fraction* | | | | |
| AP | 0-15 | 39.0 | 38.0 | 14.6 |
| BW | 15-40 | 40.0 | 14.0 | 19.2 |
| BWK | 40-56 | 20.0 | 19.0 | 17.9 |
| *Fine clay fraction* | | | | |
| AP | 0-15 | 19.0 | 40.0 | 12.5 |
| BW | 15-40 | 41.0 | 32.0 | 17.9 |
| BWK | 40-56 | 35.0 | 48.0 | 20.1 |

* = the data is average of three replications

**Table. 4.** Effect of fertilizer treatments on mica, vermiculite and smectite in clay fractions*

| Horizon | Depth | Fertilizer treatment | | | | |
|---|---|---|---|---|---|---|
| | (cm) | Control | N | NP | NPK | FYM |
| | | Mica (g/100 g) | | | | |
| *Coarse clay fraction* | | | | | | |
| AP | 0-15 | 27.0 | 27.0 | 26.0 | 34.0 | 25.0 |
| BW | 15-40 | 36.0 | 27.0 | 24.0 | 37.0 | 23.0 |
| BWK | 40-56 | 23.0 | 24.0 | 21.0 | 41.0 | 26.0 |
| *Fine clay fraction* | | | | | | |
| AP | 0-15 | 22.0 | 33.0 | 17.0 | 21.0 | 36.0 |
| BW | 15-40 | 19.0 | 21.0 | 38.0 | 20.0 | 21.0 |
| BWK | 40-56 | 38.0 | 55.0 | 30.0 | 19.0 | 25.0 |
| | | Vermiculite (g/100 g) | | | | |
| *Coarse clay fraction* | | | | | | |
| AP | 0-15 | 21 | 20 | 19 | 10 | 17 |
| BW | 15-40 | 26 | 28 | 25 | 16 | 21 |
| BWK | 40-56 | 20 | 16 | 14 | 25 | 13 |
| *Fine clay fraction* | | | | | | |
| AP | 0-15 | 42 | 40 | 40 | 46 | 25 |
| BW | 15-40 | 46 | 35 | 35 | 42 | 25 |
| BWK | 40-56 | 32 | 3 | 32 | 48 | 37 |
| | | Smectite (g/100 g) | | | | |
| *Coarse clay fraction* | | | | | | |
| AP | 0-15 | 20.3 | 17.2 | 16.2 | 12.6 | 18.5 |
| BW | 15-40 | 21.3 | 16.3 | 17.6 | 20.9 | 17.6 |
| BWK | 40-56 | 19.4 | 20.6 | 19.6 | 33.0 | 20.9 |
| *Fine clay fraction* | | | | | | |
| AP | 0-15 | 29.8 | 23.9 | 16.1 | 29.8 | 27.5 |
| BW | 15-40 | 32.9 | 26.1 | 22.5 | 19.2 | 28.7 |
| BWK | 40-56 | 26.8 | 17.4 | 31.5 | 27.5 | 27.5 |

* = the data is average of three replications

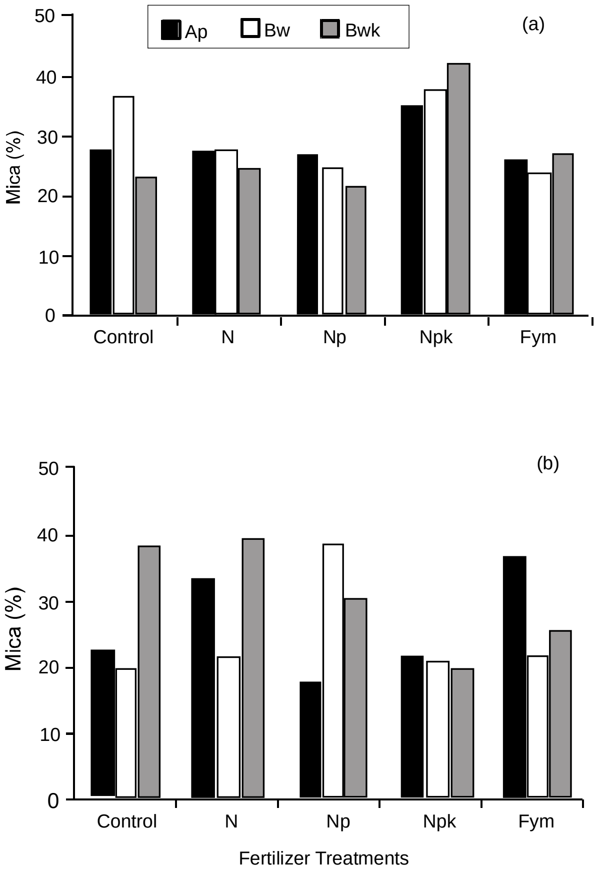

**Fig. 1.** Fertilizer treatment effect on mica: (a) coarse clay (2-0.2 µm) and (b) fine clay (<0.2 µm) based on total K contents assuming 10% $K_2O$ in crystal (Jackson, 1979).

FYM and NP treatments as compared to other fertilizer treatment. As against NPK, in NP treatments, mica decreased as the profile depth increased. In case of the control treatment, mica was 27 g/l00 g soil. In AP, it increased in BW and decreased in BWK horizon. In treatment with N, mica was identical in the upper two depths and decreased in the lowest profile depth. Mica in FYM treatment was 25, 23 and 26 g/l00 g in 0-15, 15-40 and 40-56 cm depths, respectively.

In fine clay fraction, FYM treatment had the highest mica in Ap horizon and the lowest at this depth was recorded in NP treatment. Mica in BW horizon decreased in all fertilizer treatments except in NP treatment, wherein it increased considerably. Maximum amount of mica (55 g/100 g) was observed in N treatment, that was substantially higher as compared to all other fertilizer treatments at all depths of the soil profile. On the basis of total mica of the three horizons in fine clay fraction, the highest mica was recorded in N treatment followed by NP, FYM control and NPK treatments. In NP treatment, mica in fine clay increased from Ap to Bw horizon, suggesting greater weathering at surface than subsurface soil. The result of the study is in line with those reported by Akhtar and Ali (1993), who reported K depletion in intensive rice-wheat cropping system without K fertilizer application in an alluvial camborthid soil.

**Changes in vermiculite.** Vermiculite in coarse clay fraction was greater in the control, N and NP than in FYM and NPK treatments in the upper two profile depths (Table 4, Fig. 2). In the lowest profile depth, vermiculite was the highest in NPK as compared to all other fertilizer treatments. In NPK treatment, vermiculite in coarse clay fraction increased from AP to BWK horizon and was 1.6 and 2.5 times in BW and BWK horizon, respectively, as compared to AP horizon. In the control, N, NP and FYM treatments, vermiculite increased from AP to BW horizon and, thereafter, it decreased in Bwk horizon. In fine clay fraction in the three profile depths, cumulative vermiculite followed the order NPK > Control > N> NP> FYM treatments. Vermiculite in fine clay fraction in the control increased in Bw as compared to AP and then decreased substantially in BWK as compared to BW horizon. In the case of N treatment, vermiculite decreased in BW in comparison to AP and was identical in both BW and BWK profile depths. In NP treatment, vermiculite decreased with increase in the soil depth. In fine clay fraction, in NPK treatment vermiculite decreased in BW and then increased in BWK depth. In case of FYM treatment, vermiculite was identical in AP and BW depths and it was 1.48 times more in Bwk depth. On overall basis, vermiculite in fine clay fraction was almost double than that in the coarse clay fraction in all the fertilizer treatments and it was also, in general, more than mica in the fine clay fraction. This evidently indicates greater transformation of mica to vermiculite. These results are in line with the finding of Fanning *et al.* (1989) who reported transformation of mica to vermiculite on weathering.

**Changes in smectite.** Smectite, in coarse clay fraction, in AP horizon followed the order of control >FYM>N>NP>NPK treatments (Table 4, Fig. 3). In NPK and NP treatments, smectite increased substantially with the depth, with comparatively meagre increase in case of NP. In N and FYM treatments, smectite decreased in Bw depth and increased in BWK depth, and *vice versa* in the control treatment. In fine clay

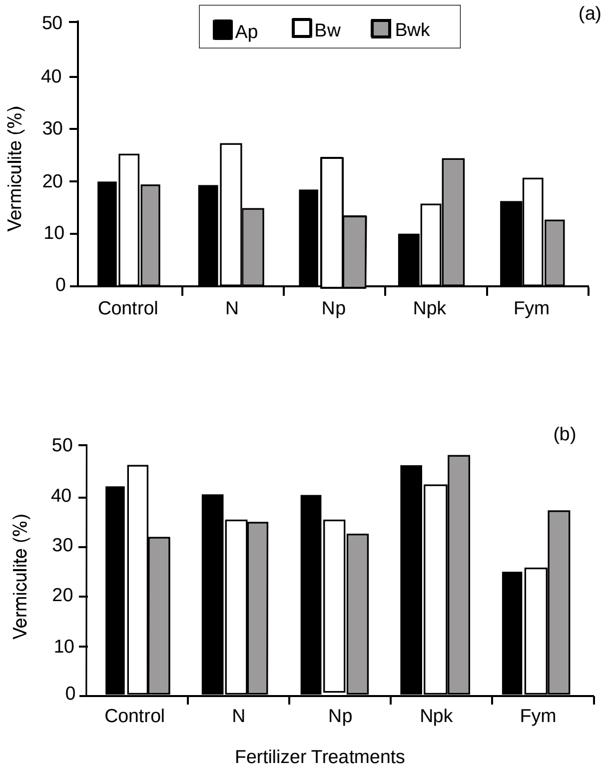

**Fig. 2.** Fertilizer treatment effect on vermiculite: (a) coarse clay (2-0.2 µm) and (b) fine clay (<0.2) µm) based on Ca/Mg and K/NH$_4$ CEC (Jackson, 1979).

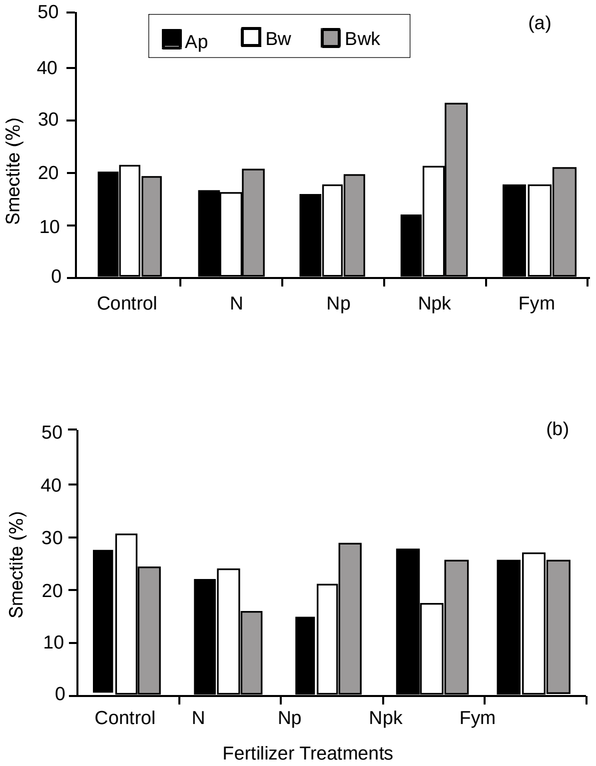

**Fig. 3.** Fertilizer treatment effect on smectite: (a) coarse clay (2-0.2 µm) and (b) fine clay (<0.2) µm) based on Ca/Mg and K/NH$_4$ CEC (Jackson, 1979).

fraction, maximum amount of smectite (29.8 g/l00 g) was observed in AP depth in control and NPK treatments followed by FYM treatment. In these three fertilizer treatments, smectite was quite higher than N and NP treatments that had 23.9 and 16.l g/l00 g smectite, respectively. In BW depth maximum smectite was recorded in the control. In BWK depth, smectite was in the order of NP > NPK = FYM > Control > N treatment. This reveals that fertilizer treatments invariably affect smectite content in soil. Tributh *et al.* (1987) observed that cropping without K application enhanced depletion of structural K in mica minerals leading to transformation of mica into vermiculite and smectite.

It can be concluded from the study that changes in clay mineral with profile depth of soil do occur through long term K-fertilizer application to sugar cane crop. Thus potassium application to sugar cane crop may be based on mineralogy of the soil at various depth.

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