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# POTASSIUM DEPLETION IN AGRICULTURAL SOILS OF BANGLADESH AND ITS POSSIBLE IMPACTS ON MINERAL ALTERATION: SOME EMPIRICAL CONSIDERATIONS

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In Bangladesh presently, out of a total of 8 million hectares of agricultural lands, 37 percent is single, 51 percent is double and 12 percent is triple cropped (BBS 2007). These intensively used soils, as a result, are gradually loosing their inherited nutrients and quality stealthily due to lack of adequate fallow period needed for natural replenishment and recuperation (Hussain *et al.* 2013). Moreover, alternate oxidation- reduction processes caused by seasonal flooding and irrigation hasten weathering of both primary and secondary minerals resulting in accumulation of altered and residual minerals in soil bodies (Beckett 1964 and Bloomfield 1952). Churchman (2000) noted that minerals are altered by hydrolysis in water usually containing $H^+$ ions, organic chelating agents and other soluble reagents, because they are not in equilibrium with their environment.

The topsoils in the agricultural fields of Bangladesh have become subjected to exploitation of nutrient elements warranting heavy application of chemical fertilizers. But that kind of judicious recommendation of fertilizers is absent. The recommended fertilizer dozes by BARC (BARC 2005) is a kind of thumb rule approach for non-homogenous big areas rather than based on specific requirements of individual soils and crops with a close evaluation on various nutrients gain and loss. Thus, scientists are apprehensive that the nutrient content and soil health are getting steadily deteriorated due to excessive use of land. The heavy loss of potassium due to crop removal on the one hand and leaching from the soils on the other hand is a matter of grave concern (Ahmad and Zaman 1998).

The minerals already present in the soil and the deposition of the weatherable potassium bearing silicate minerals on floodplain soils due to siltation is a major source of supply of potassium for growing crops. So the knowledge about transformation cycle of potassium bearing minerals in the clay complex and the potassium release mechanisms in soil will be helpful in understanding the reported mining of potassium (Ahmed and Zaman 1998). This possibly prompted the authors to empirically look into the alteration mechanisms and ultimate fate of K–bearing minerals in the clay complex of some Bangladesh agricultural soils (Figs. 1a and 1b).

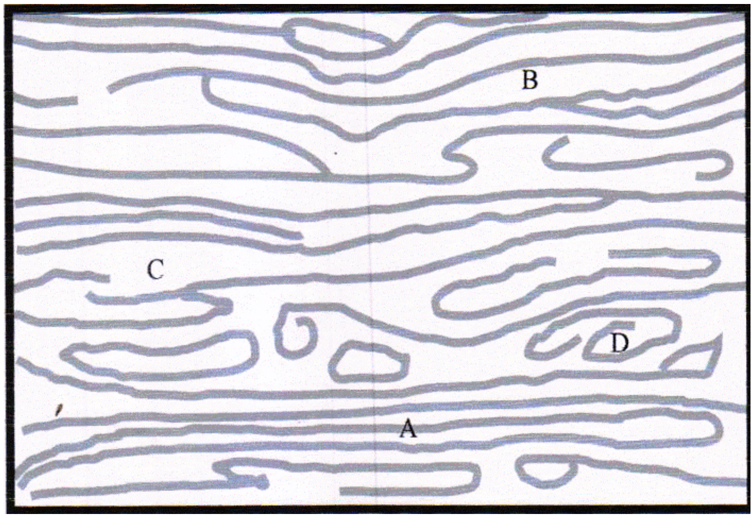

Fig.1a. Conceptual model of alteration of mica (illite) in clay complex of soils A= Mica (Illite), B= Vermiculite, C= Montmorillonite, D= Intergrades (Jackson 1965).

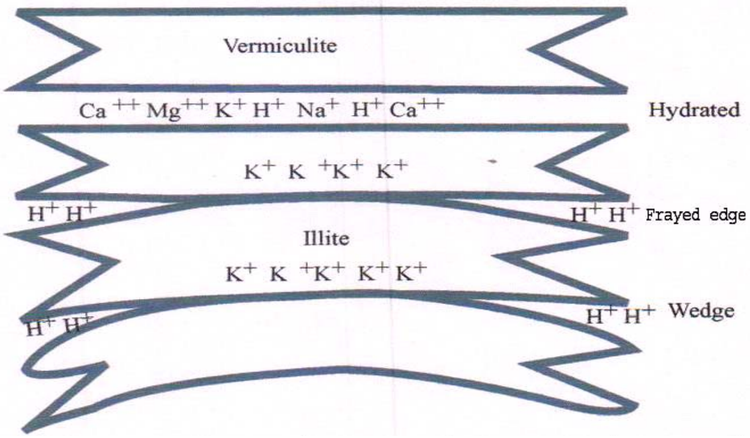

Fig. 1b. Mica (illite) is altered to vermiculite by gradual removal of $K^+$by $H^+$ from edges of clay crystals (Fanning and Keramidas 1977).

Results presented in Table 1 indicate that silicate clay minerals are dominant in clay fraction with various quantities of silicon ($SiO_2$), aluminum ($Al_2O_3$), iron ($Fe_2O_3$), magnesium (MgO) and potassium ($K_2O$). The $SiO_2/R_2O_3$) molar ratios indicate that the minerals in the clay complex are of 2:1 layer silicate types such as illite, vermiculite, montmorillonite and mixed layer minerals etc. The considerable quantity of potassium ($K_2O$) indicates that there is around 40% mica (illite) (Jackson 1965). High quantities of

Table 1. Chemical composition of clay fraction separated from some selected soils developed on various parent materials in Bangladesh.

| Soil Clays* (< 2μ fraction) | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MgO | $K_2O$ | Exch. K | CEC | $\frac{SiO_2}{R_2O_3}$ molar ratio | CIA |
|---|---|---|---|---|---|---|---|---|---|
| | (%) | (%) | (%) | (%) | (%) | cmol($p^+$)/kg | | ratio | (%) |
| Brahmaputra alluvium soil | 53.40 | 20.90 | 8.90 | 2.05 | 2.71 | 0.31 | 10.55 | 3.42 | 64 |
| Ganges alluvium soil | 53.70 | 19.00 | 8.70 | 2.30 | 2.95 | 0.57 | 23.77 | 3.69 | 61 |
| Meghna alluvium soil | 54.10 | 17.97 | 8.10 | 2.40 | 2.70 | 0.36 | 13.06 | 3.86 | 62 |
| Teesta alluvium soil | 52.40 | 18.70 | 8.00 | 3.40 | 2.70 | 0.33 | 12.05 | 3.73 | 63 |
| Madhupur clay soil | 52.80 | 18.25 | 9.70 | 2.50 | 2.68 | 0.23 | 8.55 | 3.68 | 56 |

*Note: Fusion analysis of the deferrated clay was performed in the laboratory of Soil, Water and Environment Department in the University of Dhaka. For separation of clay fractions and their fusion analysis the procedure of Jackson (1975) was followed. Exchangeable K and cation exchange capacity (CEC) were determined by standard $NH_4OAc$ method. Chemical Index of Alteration (CIA) was calculated from the silicate analysis of the samples. CIA = $Al_2O_3$/ ($Al_2O_3$+ $Fe_2O_3$+CaO+$Na_2O$) x 100.

Si, Al, Fe and K in the clay fraction further indicate the presence of high quantites of ferroaluminosilicate minerals. The clay complex in these soils where potassium bearing mica may undergoes depotassication and through many stages of intergradations finally forms 2:1 expanding lattice clay minerals (Fig. 1a). Most Bangladesh soils are subject to almost continuous wetland cultivation (rainfed and irrigated), and hence remain saturated during most part of the year and the transformation in the clay complex under such wet situation presumably occurs all through the year in the following way:

$$\text{Mica} \xrightarrow[\text{(depotassication)}]{-\,\text{K}} \text{Illite} \xrightarrow[\substack{+\,\text{Ca}^{++},\ \text{Mg}^{++},\ \text{H}^{+} \\ \text{(depotassication)}}]{-\,\text{K}} \text{Vermiculite} \xrightarrow[\substack{+\,\text{Mg}^{++},\ \text{H}^{+} \\ \text{(hydration)}}]{+\,\text{Ca}^{++}} \text{Montmorillonite + Mixed layer minerals}$$

The clay complex in soils is assumed to be constituted of mica, illite, vermiculite and smectite and innumerable intergrades in various proportions and is composed of the elements presented in Table 1. All these minerals are believed to be of allogenic origin (Hussain 1998). Synthesis of new clay minerals in the clay complex through alteration of mica is a very complicated process which does not occur uniformly along the cleavage edges of mineral lattices (Figs. 1a and 1b) (Jackson 1965 and Fanning and Keramidas 1977). As a result clay minerals like illite, vermiculite, smectite and mixed layer minerals and their resulting intergrades are being synthesized conveniently under different site conditions of soils (Jackson 1965). According to Churchman (2000) alteration of a particular clay mineral begins with the disruption of its weakest bond (Fig. 1b). The bonding of silica tetrahedra varies according to (a) the manner in which the tetrahedra are joined, (b) the extent of substitution of Si for Al and (c) the extent of incorporation of cations in the structure to balance the negative charge. The chemical indexes of alteration (CIA) in the clay fraction ranges from 56 to 64% (Table 1). These results indicate that base elements are quite high in the clay minerals. Alteration of clay minerals in the clay complex is still in the initial stage (Churchman 2000).

Perhaps, it is important to note that the process of the release of $K^+$ through weathering of both primary and secondary silicate minerals present in the soil system may temporarily be reversed by fixation of K by expanding lattice minerals (Murthy *et al.* 1975). The favorable conditions for $K^+$ fixation are the presence of large quantity of expanding lattice 2:1 clay minerals like smectite, vermiculite and their intergrades as well as the availability of $K^+$ in solution phase. The occurrences of K rich weatherable minerals in the soil system hasten the process of release of K into solution phase (Beckett 1964). The net result will be unceasing loss of K and alteration of minerals in the clay complex (Figs. 1a and1b) (Sawhney 1969 and Thompson and Ukrainezyk 2002). Undoubtedly the depotassication process is long in soils and very well being slow in the neutral and slightly acidic soils (Fanning and Keramidas 1977). More than 50% $SiO_2$ in the clay fraction indicates that clay minerals in the clay complex are quite stable and the pedochemical weathering processes are slow as there is virtually little amount of iron and magnesium in the clay fraction (Table 1).

The quantity of $K^+$ depletion in soil clays is not appreciable as evidenced from total K contents in the clay fraction determined by fusion analysis (Table 1). From these results, therefore, the K release capacity of minerals cannot be determined. Beckett (1964) used the quantity-intensity (Q-I) relationships for determining the quantity of K that can be released and be taken up by plants. Another useful way of estimating K availability in soil is the determination of exchangeable $K^+$ which is based on an assumption that soils containing more than 0.2 cmol/kg clay will not need application of any fertilizer containing potassium (Haque *et al.* 1995) as soil solution will contain enough $K^+$ to meet plants needs. The Q/I relation and exch. $K^+$ measurements are the well established index of K availability. It will be wise to decide any application of K-fertilizer based on the above index.

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