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Effect of Moisture Regimes on Ion Sorption in Old Brahmaputra Floodplain Soil

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Abstract: A laboratory experiment was carried out on ion [viz. NH_4^+ , C, Ca^{2+} , P ($\text{HPO}_4^{2-} + \text{H}_2\text{PO}_4^-$), SO_4^{2-} and NO_3^-] sorption behaviour of Old Brahmaputra Floodplain soil with a view to examine the amount of ion sorbed by soil when recommended doses of N, P, K and S fertilizers are applied at different moisture regimes i.e. 5 cm standing water (low concentration), saturated condition (medium concentration) and field capacity (high concentration). Results showed that there was a wide variation in ion sorption for different moisture regimes as well as times. In general, the sorption of different cations and anions increased with the increase in ionic concentration i.e. ionic strengths of the solution and the maximum sorption was found at saturated condition (medium concentration). The sorption of Ca^{2+} was the highest followed by NH_4^+ and K^+ . Among the anions the P sorption was the highest followed by NO_3^- and SO_4^{2-} .

Key words: Ion sorption, moisture regimes, soil

Introduction

The fertilizers that we are using in the fields for crop production undergo various changes in soils (Ponnamperuma, 1985; Rolston *et al.*, 1990). When the fertilizers are added to soils the natural physical, chemical as well as biological equilibriums are and a new equilibrium is established after adsorption, desorption, fixation, transformation, translocation, losses and uptake by crops (Verloo, 1993). In addition to temperature, and other soil and climatic factors, moisture regimes of soils greatly influence the gravity and extent of these changes.

In general, the fertilization practices are done under different soil moisture regimes. During wetland rice cultivation, fertilizers are applied either at saturated condition or at water logging condition. On the other hand, for dry land cultivation fertilizers are generally applied in moist or field capacity condition. Because of the wide changes in soil moisture regimes, the nutrient concentrations in soil solution will be different if only the recommended doses of fertilizers are applied. This changes in nutrient concentration in soil solution will ultimately determine the amount of nutrient to be sorbed by soil at a particular situation. Ali *et al.* (1990) reported a higher nutrient sorption by soils at field capacity than at saturated condition. In order to sustain soil fertility, minimize the loss as well as to increase the fertilizer use efficiency sorption study is needed. The present piece of research work was, therefore, formulated to see the effect of various moisture regimes on ion sorption by Old Brahmaputra Flood plain Soil.

Materials and Methods

The laboratory study was conducted in the Department of Soil Science, Bangladesh Agricultural University, Mymensingh to evaluate the effect of moisture regimes i.e. 5 cm standing water (low concentration), saturated condition (medium concentration) and field capacity (high concentration) on ion like NH_4^+ , K^+ , Ca^{2+} , P ($\text{HPO}_4^{2-} + \text{H}_2\text{PO}_4^-$), SO_4^{2-} and NO_3^- sorption behaviour of Old Brahmaputra Floodplain soil belonging to Sonatala series. A number of soil samples were collected from the farmers field of Churkhai, Mymensingh from which a composite sample was prepared. The soil sample was air dried, ground, sieved and kept in a plastic container for subsequent analysis. The soil was silt loam having pH 6.6, organic matter 1.6%, NH_4^+ -N 24.3 mg kg^{-1} , NO_3^- -N 16.3 mg kg^{-1} , available P 12.5 mg kg^{-1} , exchangeable K 0.18 me%, available S 15.5 mg kg^{-1} , exchangeable Ca 8.5 me% and CEC 16 me%. Multi-ion solutions containing NH_4^+ , K^+ , Ca^{2+} , P ($\text{HPO}_4^{2-} + \text{H}_2\text{PO}_4^-$), SO_4^{2-} and NO_3^- of three different concentrations were prepared by dissolving NH_4NO_3 , $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, $\text{Ca}(\text{H}_2\text{PO}_4)_2 \cdot \text{H}_2\text{O}$ and KCl salts in water (Table 1). The concentrations were chosen considering the

concentration of soil solution when recommended doses of N, P, K and S fertilizers are added to soil at the moisture regimes as stated above. For studying the different ion sorption, five sets of plastic bottles with three replications were prepared for 5 different times i.e. 5, 10, 24, 48 and 72 hours for each of low, medium and high concentrations. Eight g of soil was taken in each of 45 bottles. Of these 45 bottles 15 were earmarked for solution of low concentration, 15 for medium concentration and 15 for high concentration. Eighty ml of respective sorption solution was added to each of 15 bottles, shaken for 30 minutes in a horizontal shaker and allowed to stand for above mentioned time for sorption. At the end of allocated time the suspensions were filtered through retentive filter paper.

The P concentration in the equilibrium solution was determined colorimetrically while the SO_4^{2-} concentration was estimated by spectrophotometer following BaCl_2 precipitation method (Bardsley and Lancaster, 1960). The NH_4^+ -N and NO_3^- -N were determined by distillation method (Keeney and Nelson, 1982) and the K^+ and Ca^{2+} concentrations were determined with the help of a flame photometer (Jackson, 1962). The difference in $\text{P}_2\text{SO}_4^{2-}$, NO_3^- , NH_4^+ , K^+ and Ca^{2+} concentrations between the initial multi-ion solution and the equilibrium soil solution was taken as the amount sorbed by soil.

Results and Discussion

Cation sorption: Results in Fig. 1 show that at low concentration the sorption of the cations K^+ , Ca^{2+} and NH_4^+ increased remarkably up to 5 hours and continued up to 10 hours where the sorption of Ca^{2+} was the highest followed by NH_4^+ and K^+ . The sorption of NH_4^+ further increased up to 24 hours at the expense of a decrease in the sorption of C and Ca^{2+} . Afterwards the sorption of all cations was virtually ceased although a slight increase or decrease was noticed. It appears further from the Fig. 1 that within 5 to 10 hours the sorption sites were saturated with the cations. As the NH_4^+ sorption continued increasing with the passes of time up to 24 hours a decrease occurred simultaneously in case of sorbed C and Ca^{2+} where the decrease of C was more prominent. This was probably because of high concentration of NH_4^+ over the K^+ as well as for almost equal ionic radius.

The trend of cation sorption by Sonatala soil at medium concentration (saturated condition) was almost similar to that of low concentration (5 cm standing water) but the amount of sorption was much higher in medium concentration (Fig. 2). This was possibly because of higher ionic strength of medium concentration over low concentration. The sorption of NH_4^+ gradually increased after 5 hours but a slight decreasing trend

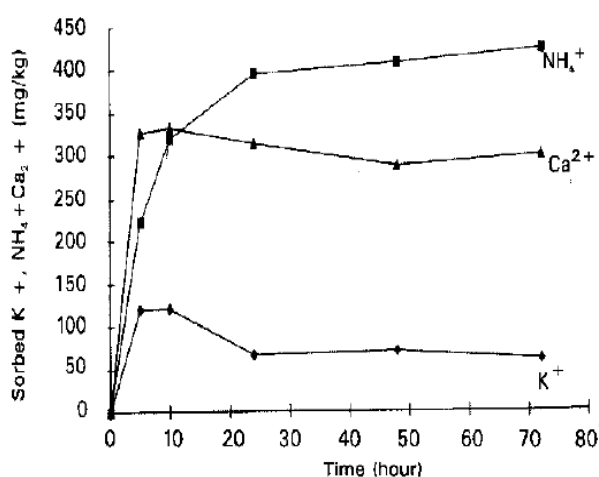


Fig. 1: Cation sorption (mg kg^{-1} in Sonatola soil at low conc. (5 cm standing water)

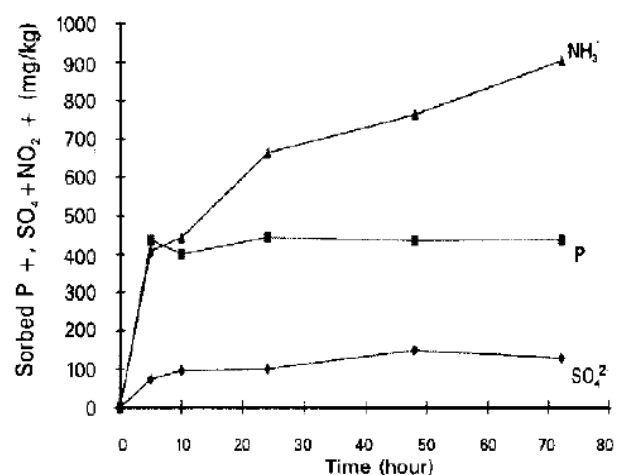


Fig. 4: Anion sorption (mg kg^{-1} in Sonatola soil at low conc. (5 cm standing water)

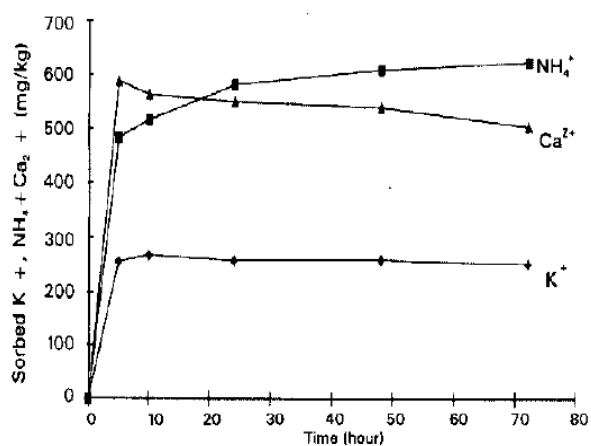


Fig. 2: Cation sorption (mg kg^{-1} in Sonatola soil at medium conc. (saturated condition) of soil

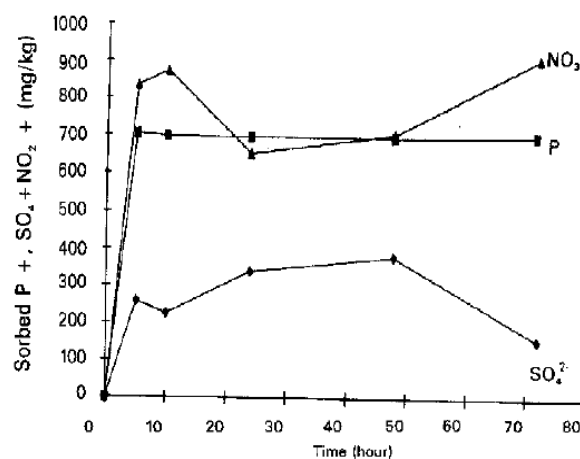


Fig. 5: Anion sorption (mg kg^{-1} in Sonatola soil at medium conc. (saturated condition) of soil

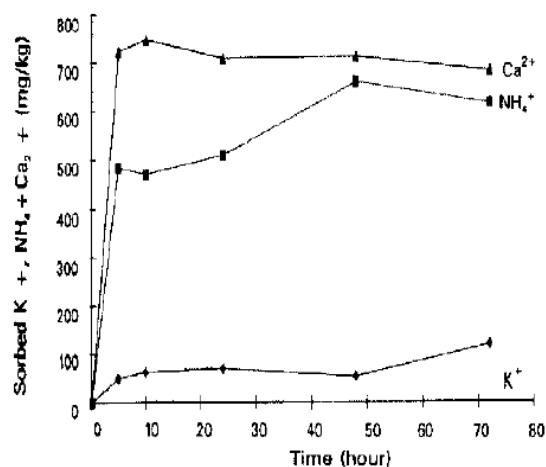


Fig. 3: Cation sorption (mg kg^{-1} in Sonatola soil at high conc. (field capacity)

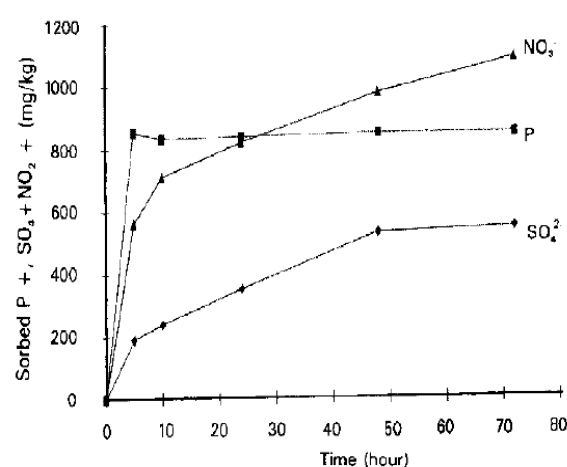


Fig. 6: Anion sorption (mg kg^{-1} in Sonatola soil at high conc. (field capacity)

Table 1: Concentrations of different ions in solutions prepared for sorption study

Moisture regime	Water content up to 15 cm depth	NH ₄ ⁺ (mg L ⁻¹)	K ⁺ (mg L ⁻¹)	Ca ²⁺ (mg L ⁻¹)	P(HPO ₄ ²⁻ + H ₂ PO ₄)	SO ₄ ²⁻ (mg L ⁻¹)	NO ₃ (mg L ⁻¹)
5 cm standing water (low conc.)	135	47.6	29.6	56.5	44.4	66.7	163.9
Saturated (medium conc.)	85	75.6	47.1	89.5	70.6	105.9	260.5
Field capacity (high conc.)	70	91.8	57.1	108.9	85.7	128.9	316.9

Table 2: Ionic strength of equilibrium soil solutions of different times

Concentration	0 (HAAS)	5 (HAAS)	10 (HAAS)	24 (HAAS)	48 (HAAS)	72 (HAAS)
Low conc.	0.0104	0.0095	0.0094	0.0094	0.0093	0.0089
Medium conc.	0.0140	0.0138	0.0140	0.0131	0.0132	0.0135
High conc.	0.0191	0.0188	0.0195	0.0192	0.0180	0.0173

was noticed in case of Ca²⁺ up to 72 hours. The status of K⁺ remained almost static from 5 - 72 hours. Unlike low concentration, the slight increase in NH₄⁺ sorption was noted at the expense of slight decrease of Ca²⁺.

The sorption of cations by Sonatala soil at concentration of field capacity showed a different trend (Fig. 3). The sorption of Ca²⁺ largely increased over other cations as well as other concentrations ranging from almost 680 - 750 mg kg⁻¹ soil. This amount was almost 200 mg Ca²⁺ kg⁻¹ soil higher than the medium concentration. It is interesting to mention here that as the Ca²⁺ sorption increased by about 200 mg kg⁻¹ soil over the medium concentration, the sorption of IC decreased by almost 200 mg kg⁻¹ soil, but the status of NH₄⁺, on the other hand, was almost similar or slightly less than the medium concentration. Between 5 and 72 hours the cations showed some increase or decrease without following any trend. When the sorption of one cation increased, the sorption of others decreased maintaining an equilibrium condition over the time. The ionic strength of equilibrium solution did not vary remarkably over the time which also adds to the justification of the above findings (Table 2).

It appears from the results in Fig. 1 - 3 that when these three cations (Ca²⁺ and K⁺) were added to Sonatala soil at different moisture levels, the Ca²⁺ was absorbed in higher amounts than the NH₄⁺ and K⁺. Here the sorption of K⁺ was suppressed by both NH₄⁺ and Ca²⁺. The correlation between Ca²⁺ and NH₄⁺, NH₄⁺ and K⁺, Ca²⁺ and K⁺ (r = 0.650, 0.339 and 0.022 respectively) indicated that the K⁺ sorption was highly suppressed by the Ca²⁺ than the NH₄⁺ although the sorption of NH₄⁺ was nearly equal to Ca²⁺.

Anion sorption: It appears from results in Fig. 4 that the sorption of different anions SO₄²⁻ and NO₃⁻ by Sonatala soil at low concentration (5 cm standing water) increased with the passes of time up to 72 hours, the highest time under study, where the increase of NO₃⁻ sorption was more prominent than SO₄²⁻. The sorption of P was maximum up to 5 hours and then maintained almost a stable status up to 72 hours although some increase or decrease was noted. Among these anions the sorption of NO₃⁻ was the highest followed by P.

The sorption of all anions further increased over the low concentration when the solution of medium concentration (saturated condition) was added (Fig. 5). Like the low concentration the maximum sorption of almost 700 mgP kg⁻¹ soil was sorbed within 5 hours and afterwards no further sorption was found up to 72 hours. Between 5 and 72 hours the sorption of SO₄²⁻ and NO₃ fluctuated. When there was a sorption of NO₃, a decrease of SO₄²⁻ was noted but the rate of increase/decrease of sorption was almost the same. Like the low and medium concentration, the maximum sorption of P was also occurred within 5 hours and remained almost stable up to 72 hours when solution of higher concentration (field capacity) was added. The amount of sorbed P increased by about 160 mg kg⁻¹ soil over the medium concentration i.e. saturated condition (Fig. 6). The sorption of NO₃⁻ and SO₄²⁻, on the contrary, gradually increased up to 72 hours.

It appears further from Fig. 4 - 6 that the sorption of NO₃ superseded SO₄²⁻ and P sorptions at both low and medium concentrations. But at higher concentration the P sorption

superseded NO₃ up to 24 hours. As a consequence of increased P sorption the NO₃ sorption was suppressed by about 160 - 275 mg kg⁻¹ soil over the medium concentration. Results in Fig. 4 - 6 further indicate that the sorption of P by Sonatala soil progressively increased with increasing concentration of P in solution. The stabilization of P sorption from 5 - 72 hours reveals that at first P was sorbed by the soil because of the higher sorption affinity. When the sorption of P was satisfied maintaining an equilibrium condition between soil and soil solution for each concentration, the sorption of SO₄²⁻ and NO₃ took place. The sorption of NO₃ in Sonatala soil was found higher in all concentrations because of its higher content in solutions over the SO₄²⁻. The ionic strength of equilibrium solution also maintained a stability over the period. The strong, medium and weak correlation of P with Ca²⁺ (r = 0.985), SO₄²⁻ (r = 0.747) and NO₃⁻ (r = 0.471) respectively indicated that these ions competed with each other for sorption sites at different degrees.

Conclusion

It is clear from the above that when same doses of fertilizers are applied to a soil at various moisture levels, different amount of added fertilizers are sorbed by the soil. At water logging condition lesser amount of added nutrients are sorbed because of lower ionic strength due to dilution. At field capacity, on the other hand, higher amount of Ca²⁺, P, SO₄²⁻ and NO₃⁻ are sorbed but the vital nutrient ions NH₄⁺ and K⁺ are displaced by Ca²⁺ and became liable to be lost through percolating water. For sustaining fertility, it is desirable to get all the nutrient ions sorbed by soil in a balanced proportion. It appears from this study that the ionic concentration or the ionic strength which reached in soil solution of a saturated soil when same doses of fertilizers are applied, is suitable to get all the ions sorbed by the soils in relatively balance amount. Hence, different fertilizer doses may be recommended for different moisture regimes of a soil taking the ionic concentration in solution of a saturated soil under present recommended doses as standard. However, further study is necessary to come to a conclusion in this respect.

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