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Potassium retention and release behavior of Old Brahmaputra Floodplain and Madhupur Terrace soils

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Abstract

A laboratory experiment was carried out to see the distribution of sorbed potassium (K) in Old Brahmaputra Floodplain and Madhupur Terrace soils and its subsequent release behaviour for getting an idea on K fertility of these two soils. For sorption, four different concentrations 0, 10, 20 and 30 mg K L^{-1} were added and kept for 15 days. After the allocated time, one sample of the treated soils was repeatedly extracted with 1N NH_4OAc solution to see the K release capacity and another sample was sequentially extracted with distilled water, 1N NH_4OAc and H_2SO_4 for water soluble, exchangeable and non-exchangeable forms of K. The sorption of K increased progressively with increasing K concentrations of the solution. The flood plain soil sorbed higher amount of K compared to terrace soil. The terrace soils from Madhupur farm sorbed K mostly in exchangeable form whereas the flood plain soil from BAU farm sorbed mostly in non-exchangeable form. About 33-41% and 36-62% of added K were released by the first extraction for BAU farm and Madhupur soils respectively, but in following extractions the release of K from BAU farm soil was almost equal or higher than Madhupur soil. The Elovich equation showed a higher rate of K release from Madhupur soil than from BAU farm soil.

Keywords: K retention, K release, Flood plain soil, Terrace soil

Introduction

The positively charged potassium ions that are held at the edges of the clay layers and towards the outer edge of any interlayer space can be replaced easily by other cations. Quantities of K^+ released from clay and silt fractions were comparable and twice as high as from sand fractions. Interlayer K^+ released from silt and clay fractions, found important for plant K nutrition, should be considered in K fertilizer management. The released potassium comes into the soil solution from where it is taken up by plant roots. Potassium in the most interior phase in the interlayer space can only be exchanged slowly. A reverse of the above process occurs when the concentration of potassium in the soil solution is increased due to the addition of fertilizers and manures. As a result of the later process, a reserve of potassium is built up in those soils. Fortunately, some soils contain considerable amount of non-exchangeable but slowly available forms of this element. But the capacity of soils to supply nutrients is gradually declining over time due to intensive cropping with high yielding varieties. For this reason, farmers routinely apply sufficient potassium containing fertilizers to meet plant needs (Johnston, 1997).The sorption of different cation and anion increased with the increasing ionic concentration (Khanam *et al.*, 2000). The K fixation and release behaviours of the soils could be related to their mineralogical make-up (Brady, 1990). Majumder and Datta (1999) reported that the K release behaviour of the untreated soils was strongly influenced by illite, vermiculite and associated minor minerals. The present piece of research work was, therefore, formulated to see the K retention/release capacities, K buffering capacity and the distribution of different forms of K in BAU farm and Madhupur soils.

Materials and Methods

The laboratory experiment was carried out in the Department of Soil Science, Bangladesh Agricultural University (BAU), Mymensingh to see the status of different forms of Potassium and its retention and release behaviour of Old Brahmaputra Floodplain and Madhupur soils. The soil samples at a depth of 0-15 cm were collected from an experimental field of the Department of Soil Science, BAU farm, Mymensingh for Old Brahmaputra Floodplain soil and Bangladesh Agricultural Development Corporation (BADC) farm, Kakraid for Madhupur soil. The soils were air dried at room temperature, ground, sieved with the help of a 20 mesh sieve and mixed together the replicated samples for making composite sample. The BAU farm soil was silt loam (%sand 24.24, %silt 63.40 and %clay 12.36) having pH 6.72, EC 1.53 dS/m, organic matter 1.84%, mica 17% and vermiculite 36%. On the other hand, Madhupur soil was silt loam (%sand 25.24, %silt 56.40 and %clay18.36) having pH 4.83, EC 1.23dS/m, organic matter 1.33%, mica 45% and no vermiculite.

Ten gram of soil samples was taken in each of bottles earmarked for BAU farm and Madhupur soils. The bottles were divided into four groups for placement of 4 K solutions in triplicates. As such there were 4x3x2 = 24 bottles for two soils under this study. Fifty milliliter of 0, 10, 20 and 30 ppm K solutions were added to each of 3 earmarked bottles maintaining the soil: solution ratio of 1: 5. Thus there were 0, 50, 100 and 150 µg K g^{-1} soil. The bottles containing soils and solutions were shaken with a horizontal shaker for 30 minutes and kept for 15 days for retention. At the end of the allocated time, the soil suspensions were filtered through a retentive filter paper. The concentration of K^+ in equilibrium solutions were determined by flame photometer following the method described by Page *et al.* (1982). The difference in K^+ content between the initial concentration and equilibrium solution were considered the amount retained by 10 gram of soil.

The release of K from two soils was determined by successive extraction method. Two gram of each of K treated soil (those were saved from the K retention study) was taken in a centrifuge tube. Ten milliliter of 1 N NH_4OAC solution (pH 7.0) was added in each tube. The tubes were shaken for 10 minutes, and then centrifuged for 5 minutes and filtered through a retentive filter paper. The supernatant of each extraction was collected in separate bottles. The concentration of K in the extracts was determined with the help of Flame Photometer. The process of extraction was repeated until constant release of K was obtained as suggested by Mehta *et al.*, 1995. The data obtained on K release from BAU Farm and Madhupur soils were tested with simplified Elovich equation of Chien and Clayton (1980).

Ten gram treated soil was shaken in centrifuge tube with10ml distilled water, allowed to stand over night and filtered for the determination of water soluble form of K. After taking of the supernatant, 10ml of the extractant (1 N NH_4OAc, pH 7.0) was added, shaken for 15 minutes, centrifuged for 10 minutes and then filtered for the determination of exchangeable form of K. For the determination of water soluble form of K, the concentration of K in the extract was determined by flame photometer (Page *et al.*, 1982). For the determination of non-exchangeable form, 9ml distilled water and 1 ml of concentrated H_2SO_4 were added to the soil-water mixture and mixed thoroughly. It was allowed to stand for 30 minutes and at last filtered. The K concentration in the extract was determined by a flame photometer (Hunter and Pratt, 1957).

Results and Discussion

Results on the retention of K by Bangladesh Agricultural University (BAU) Farm and Madhupur soils have been presented in Fig. 1. It appears from the results that the retention of K increased with increasing the concentration of equilibrium solution in both soil. Soil from BAU Farm retained higher amount of K compared to soil from Madhupur tract. The retention of K by both soils although increased with increase in equilibrium concentrations of K, the rate of increase showed a decreasing trend after the equilibrium concentration of 0.5 mg L^{-1} in Madhupur soil. But in case of BAU Farm soil, such decreasing trend was not observed up to the equilibrium concentration of 0.5 mg L^{-1} (150 ppm K sorption solution, the highest concentration under study). It is apparent that the sorption sites of Madhupur soil were limited on the surface of clay minerals which after sorption of K have been blocked as a consequence of which the rate of sorption decreased over the concentration although the total sorbed amount increased.

Results on sorption maxima (b value) and the bonding energy (k value) of these two soils obtained from the linear Langmuir isotherm (Fig. 2) where C is equilibrium K concentration and x/m is the amount of adsorbed K. These values have been presented in Table 1. In the present study, low k values in BAU Farm soil indicated that the K in soil was tightly held by the soil particles both internally and externally. On the other hand, the high k values were found in Madhupur soil indicated that the K was held loosely (low surface energy) by soil particles compared to BAU Farm soil.

The K buffering capacity of soils under study was determined considering the equilibrium K concentration of 0.10 and 0.50 mg L^{-1} solution and their corresponding sorbed K as presented in K sorption isotherm (Fig. 1) in order to get a buffer capacity of the soils at equilibrium concentration of 0.30 mg L^{-1}. The results of the calculated buffer capacity have been presented in Table 1. It indicated that due to lowering a concentration of 0.3 mg L^{-1} in BAU farm soil will release approximately 257 mg of K to the system whereas Madhupur soil will release approximately 173 mg of K. It appears from the results that BAU farm soil was more buffered than Madhupur soil.

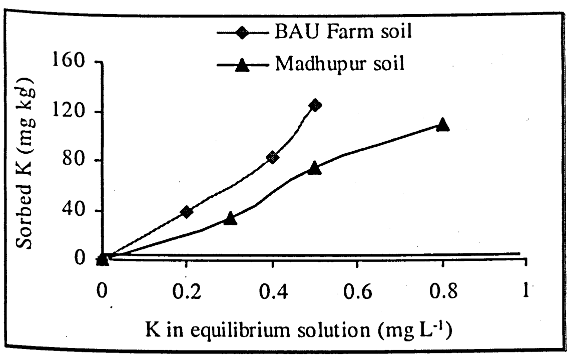

Fig. 1. Potassium adsorption isotherm of BAU farm and Madhupur soils

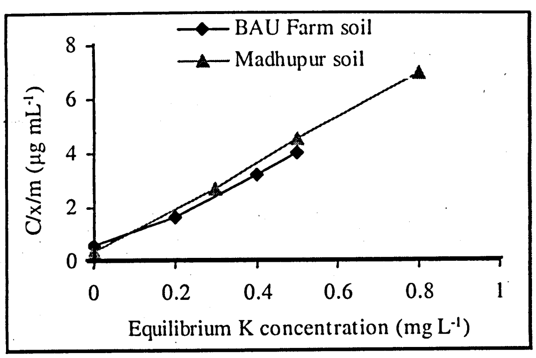

Fig. 2. Langmuir adsorption isotherm of BAU farm and Madhupur soils

Table1. Potassium adsorption parameters of the soils under study

Soils	b value(mg kg^{-1})	k value(ml μg^{-1})	Buffering capacity(mg kg^{-1})
BAU farm soil	179	9.33	257
Madhupur soil	143	17.50	172

Results on K release from BAU farm and Madhupur soils have been presented in Fig. 3 and 5. The cumulative K releases of both soils up to tenth extractions have been presented in Fig. 4 and 6. The highest release of K was found in first extraction ranging from 32-70 mg kg^{-1} soil in BAU farm soil and 35-160 mg kg^{-1} in Madhupur soil. In general, the amount of K release increased with the increase of adsorbed K. In case of BAU Farm soil, the amount of released K gradually decreased up to fifth extraction and then reached a value of 4-8 mg kg^{-1} soil in sixth extraction depending on the sorbed K content in soils. From sixth and tenth extraction the release of K remains constant. In case of Madhupur soil, on the other hand, the release of K gradually decreased up to sixth and/or seventh extraction and then reached value of 3-6 mg kg^{-1} soil which remained constant up to the tenth extraction.

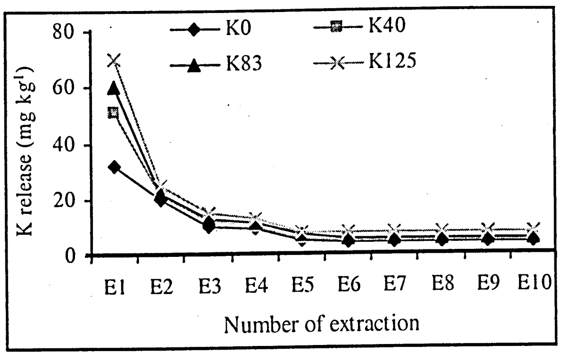

Fig. 3. Release of k from BAU farm soil

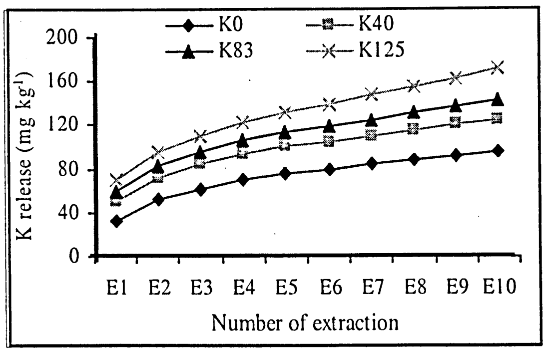

Fig. 4 Cumulative K release from BAU farm soil

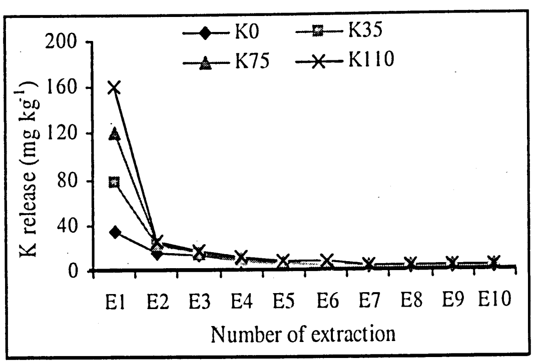

Fig. 5 Release of K from Madhupur soil

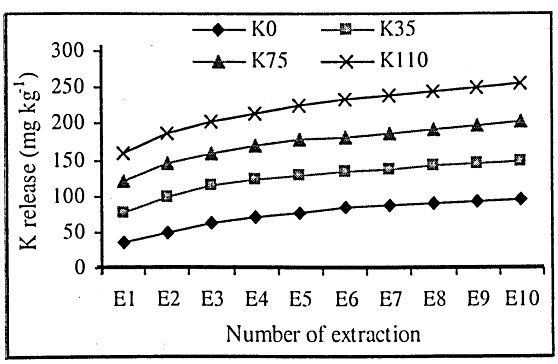

Fig.6. Cumulative K release from Madhupur soil

The cumulative K release increased with the increase of extraction time ranging from 96-171 mg kg^{-1} soil and 97-257 mg kg^{-1} soil from BAU Farm soil and Madhupur soil, respectively. Potassium desorption was tested with Elovich equation and the results have been presented in Table 2. It appears from the Table that the rate of K release was higher in Madhupur soil than BAU Farm soil. This result also supports the percent release of K from Madhupur soil which was also higher than BAU Farm soil. The cumulative release of K increased in both the soils with increasing sorption of added K. It may be mentioned here that the amount of sorbed K was less in Madhupur soil in comparison to BAU Farm soil. But in case of K releasing capacity of soil, a very high release of K was found from Madhupur soil than BAU Farm soil.

Table 2. Amount of desorbed K (mg kg^{-1}) in BAU farm and Madhupur soils

Sorbed K	Desorbed K (mg kg^{-1})	
	BAU Farm soil	Madhupur soil
K_0	8.62	8.48
$K_{40}(K_{35})$	8.94	9.96
$K_{83}(K_{75})$	9.34	10.40
$K_{125}(K_{110})$	9.93	11.07

Note: Number within bracket indicates sorption in Madhupur soil

A calculation on percent release of K at different extraction indicated that in general, the release of K showed wide variation in percent released K between number of extraction and soils under study. About 33-41% and 36-62% of K were released from BAU Farm and Madhupur soils respectively in first extraction. In second extraction, the percent release decreased from 15-21% in BAU Farm soil whereas in Madhupur soil a decrease of 10-15% was observed. In subsequent extractions, the percent release further decreased to a stable value of 4-5% in sixth extraction in BAU Farm soil but in Madhupur soil it was 2-3% in eighth extraction which remained static up to tenth extraction.

A part of the soil samples used for K sorption study was saved and analyzed for different forms of K i.e. water soluble, exchangeable and non-exchangeable in addition to initial soil. The water soluble, exchangeable as well as non-exchangeable K were increased with increasing rate of K application in both BAU Farm and Madhupur soils (Fig. 7 and 8). In BAU Farm soil, the water soluble form increased from 8-15 mg kg^{-1} soil which comes to 25-88% increase over initial level due to addition of K. In Madhupur soil, the increase was 18-27 mg kg^{-1} soil which was 22-50% increase over the initial status. This showed that percent increase in water soluble K was higher in BAU Farm soil that Madhupur soil although the amount was less when compared with Madhupur soil.

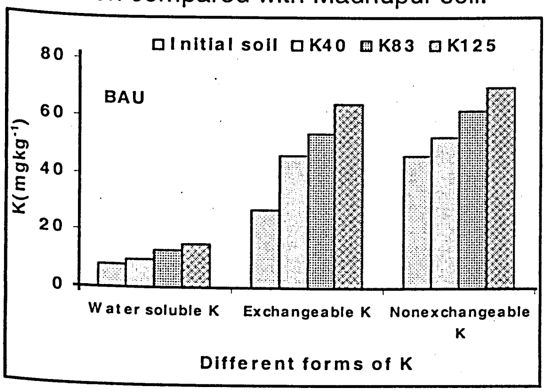

Fig. 7 Different forms of K in BAU farm soil

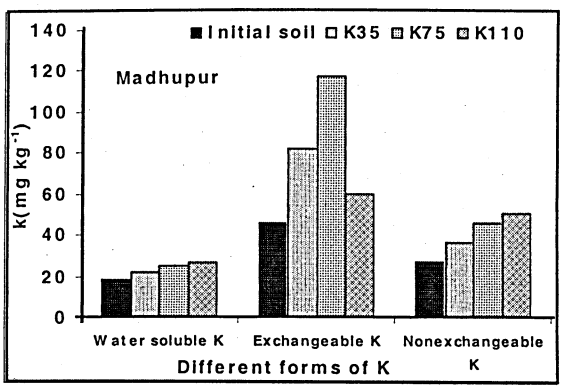

Fig. 8 Different forms of K in Madhupur soil

Like water soluble K the exchangeable K was also increased with increasing K concentration in BAU Farm and Madhupur soils. In BAU Farm soil the increase was 27-64 mg kg^{-1} soil whereas in Madhupur soil, it was 46-160 mg kg^{-1} soil due to application of 150 ppm sorption solution, the highest concentration under this study. The percent increase in exchangeable K due to application of sorption solution was rather higher in Madhupur soils (78-248%) than in BAU Farm soils (70-137%). The textural analysis of soil showed higher clay content in Madhupur soil in comparison to BAU Farm soils but silt content was relatively high in BAU Farm soil. The higher increase in exchangeable K content in Madhupur soil due to addition of K was possibly for its higher clay content.

The non-exchangeable form of K gradually increased with increasing rate of K application in BAU Farm soil. It varied from 46-70 mg kg^{-1} soil which came to 15-52% increase over initial level (Fig. 7). In Madhupur soil, the non-exchangeable K was also increased from 29-50 mg kg^{-1} soil. The percent increase in Madhupur soil was 24-72 (Fig. 8). It appears that the percentage increase in non-exchangeable K in Madhupur soil was much higher when compared with BAU Farm soil although its total amount was less than 50% of BAU Farm soil. As stated earlier BAU Farm soil contained 17% mica and 36% vermiculite (expanding clay mineral) whereas the Madhupur soil contained 45% mica but it did not contained vermiculite.

The higher amount of non-exchangeable K and lower amount of exchangeable K as found in BAU Farm soil was possibly associated with the presence of vermiculite and mica, respectively. In Madhupur soil, the higher exchangeable K was obtained due to presence of higher amount of clay and mica mainly. Vermiculite was absent in this soil hence the non-exchangeable K was low when compared with the exchangeable form of K in Madhupur soil and non-exchangeable form of K in BAU Farm soil.

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